MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *February* 14, 1879. No. 4.

Lord LINDSAY, M.P., F.R.S., President, in the Chair.

John Marshall, Esq., Albion Place, Leeds; and
R. Palmer Thomas, Esq., 13 North Villas, Camden Square, N.W.;
were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE FIFTY-NINTH ANNUAL GENERAL MEETING OF THE SOCIETY.

Progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resident	Mathematical Society	Patroness	Total Fellows	Associates	Grand Total
December 31, 1877	218	351	4	6	1	580	37	617
Since elected ...	+3	+29	...	...	...	...	+4	...
Deceased	−6	−10	...	...	...	...	−1	...
Removals	+3	−3	...	...	...	...	...	...
Resigned	...	−5	...	...	...	...	...	...
December 31, 1878	218	362	4	6	1	591	40	631

Mr. Barrow's Account as Treasurer of the Royal

RECEIPTS.

	£ s. d.	£ s. d.
Balance at Bankers' Dec. 31, 1877, as per Bankers' book... ... £240 19 9		
Less amount of outstanding cheque 15 0 0		
	225 19 9	
„ in hand of Secretary of Library Committee:		
On account of Turnor Fund	1 6 11	
On account of Library Expenses ...	20 8 6	
„ in hand on Petty Cash account	13 11 7	
		261 6 9
Dividend on £6,400 Consols	94 16 0	
„ £5,700 New 3 per cent. Stock ...	84 8 8	
„ £6,400 Consols	94 0 0	
„ £5,700 New 3 per cent. Stock ...	83 14 5	
		356 19 1
Received on account of Subscriptions:		
Arrears of Contributions	201 16 0	
255 Contributions for 1878	535 10 0	
2 Contributions for 1879	4 4 0	
33 Admission Fees	69 6 0	
29 First Contributions	48 6 0	
		859 2 0
7 Composition Fees		147 0 0
Sales of Publications:—		
At Society's Rooms during 1878	169 11 10	
At Williams & Norgate's during 1877 ...	12 7 6	
		181 19 4
Received from the Government Fund of the Royal Society on account of Mr. Gill's Expedition to Ascension		250 0 0
		£2,056 7 2

Astronomical Society, from Dec. 31, 1877, to Dec. 31, 1878.

EXPENDITURE.

	£	s.	d.	£.	s.	d.
Salaries:—						
Editor of *Monthly Notices*	60	0	0			
Assistant Secretary	150	0	0			
				210	0	0
Income Tax and House Duty				6	11	3
Fire Insurance				7	16	6
Printing and Lithography:—						
Spottiswoode & Co.	438	10	6			
Hazell, Watson, & Viney	206	13	0			
M. and N. Hanhart	15	12	0			
				660	15	6
Turnor Fund: Books purchased during year ...	75	5	0			
Library expenses: Binding	108	15	10			
Cards for Library Catalogue	8	13	4			
				192	14	2
Purchase of scarce volumes of the *Monthly Notices*				5	0	0
House expenses	29	9	8			
Wages	23	11	0			
Stamps and postage	60	10	7			
Carriage of books and parcels	6	19	9			
Stationery and office expenses	10	18	8			
Expenses of meetings	20	0	0			
Coals and gas	48	0	7			
Fittings in lavatory	19	8	0			
Sundry fittings and repairs	9	1	5			
Sundries	6	7	5			
Cheque book	0	8	4			
Bankers' commission on cheques	0	1	11			
				234	17	4
Paid on account of Mr. Gill's Expedition to Ascension (previous payment of £400. 15*s.* 6*d.* appears in last year's account. Total amount of grant £500)				99	4	6
Mrs. Jackson-Gwilt's annuity				8	19	0
Balance at Bankers' Dec. 31, 1878	605	0	3			
„ in hand of Secretary of Library Committee:						
On account of Turnor Fund	1	1	11			
On account of Library expenses ...	16	12	8			
„ in hand on Petty Cash account	7	14	1			
				630	8	11
				£2,056	7	2

Examined and found correct, J. Kennedy Esdaile.
A. A. Common.
Wentworth Erck.

Assets and present Property of the Society, January 1, 1879:—

	£	s.	d.	£	s.	d.
Balance at Bankers' Dec. 31, 1878	605	0	3			
„ in hand of Secretary of Library Committee on account of Turnor Fund	1	1	11			
„ ditto ditto on account of Library expenses	16	12	8			
„ in hand on Petty Cash account	7	14	1			
				630	8	11
Due on account of Subscriptions:—						
4 Contributions of 5 years' standing ...	42	0	0			
7 „ 4 „ ...	58	16	0			
11 „ 3 „ ...	69	6	0			
21 „ 2 „ ...	88	4	0			
47 „ 1 „ ...	98	14	0			
Various amounts	12	12	0			
Two admission fees and first contributions	6	6	0			
	375	18	0			
Less two contributions paid in advance ...	4	4	0			
				371	14	0
Due for publications	1	0	0			
„ from Williams & Norgate for sales during 1878	36	17	9			
				37	17	9

£6,400 Consols, including the Lee Fund (£300), the Turnor Fund (£450), and the Horrox Memorial Fund (£100).

£5,700 New 3 per cent. Stock, including Mrs. Jackson-Gwilt's gift (£300).

Astronomical and other MSS., books, prints, &c.

One gold medal.

Unsold publications of the Society &c.

Report of the Auditors.

We, the duly appointed Auditors, beg to lay before this General Meeting of the Royal Astronomical Society the following Report:—

1. We have examined the Treasurer's account, and an account of the assets and property of the Society, and have found and certified the same to be correct.

2. The receipts and expenditure for the past year are as stated in the Treasurer's account.

3. The cash in hand on December 31, 1878, including the balance at the Bankers', amounts to 630*l.* 8*s.* 11*d.*

4. The funded property of the Society is in a satisfactory state, and the books, instruments, and other effects have been examined as far as possible and found in a satisfactory condition.

5. We have laid on the table a list of the names of those Fellows who are now in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

J. Kennedy Esdaile.
A. A. Common.
Wentworth Erck.

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I.	83	1	XXI.	24	...
II.	84	...	XXII.	39	...
III.	...	...	XXIII.	22	...
IV.	...	...	XXIV.	25	...
V.	...	...	XXV.	7	...
VI.	50	...	XXVI.	13	...
VII.	2	...	XXVII.	2	...
VIII.	143	2	XXVIII.	79	2
IX.	25	3	XXIX.	60	1
X.	178	2	XXX.	74	4
XI.	186	2	XXXI.	107	2
XII.	12	2	XXXII.	134	2
XIII.	164	3	XXXIII.	120	4
XIV.	110	3	XXXIV.	95	7
XV.	130	2	XXXV.	79	5
XVI.	112	3	XXXVI.	45	1
XVII.	138	1	XXXVII.	59	5
XVIII.	172	...	XXXVIII.	125	14
XIX.	68	...	Index to *Monthly Notices*	607	...
XX.	40	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI., XXXVII., and XXXVIII., no complete volumes can be formed from the separate numbers in stock.

Stock in hand of volumes of the *Memoirs* :—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I. Part 1	5	...	XXII.	163	1
I. Part 2	45	..	XXIII.	159	1
II. Part 1	61	...	XXIV.	165	2
II. Part 2	23	...	XXV.	177	2
III. Part 1	70	...	XXVI.	181	2
III. Part 2	92	...	XXVII.	434	1
IV. Part 1	86	3	XXVIII.	396	1
IV. Part 2	97	3	XXIX.	421	1
V.	111	4	XXX.	172	1
VI.	131	4	XXXI.	157	1
VII.	155	3	XXXII.	174	1
VIII.	133	4	XXXIII.	178	3
IX.	142	3	XXXIV.	177	9
X.	153	1	XXXV.	127	3
XI.	165	1	XXXVI. (with M.N.)	206	15
XII.	169	...	XXXVI. (without)	16	...
XIII.	177	...	XXXVII. Part 1	372	8
XIV.	378	3	XXXVII. Part 2	320	6
XV.	149	1	XXXVIII.	313	1
XVI.	179	...	XXXIX. Part 1	291	1
XVII.	155	3	XXXIX. Part 2	308	2
XVIII.	159	...	XL.	336	1
XIX.	164	...	XLII.	321	2
XX.	162	2	XLIII.	380	3
XXI. Part 1	314	...	Index to *Memoirs*	674	4
XXI. Part 2	99	...			
XXI. 1 & 2 (together)	68	2			

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.

No. 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian Telescope (late Mr. Shearman's).
„ 10. The Variation transit instrument (late Mr. Shearman's).
„ 12. The *Fuller* theodolite.
„ 13. The Standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A quadrant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the Precession of the Equinoxes.
The *Sheepshanks* collection:—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) $4\frac{6}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; double-image micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatoreal stand, clock movement.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) A transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

No. 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; a deal box with heavy stand for theodolite; a box containing the Y piece of level; two large and three small ground-glass bubbles divided; a box containing level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. The circle is divided on silver, and is read to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

No. 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers read ing to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon, and stand.
„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{4}$ inches. Tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square: one beam compass.
„ 62. (36) A pentagraph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with the object-glass of rock crystal.
„ 70. Portable equatoreal stand.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. A double image micrometer, by Troughton and Simms.

No. 86. A $4\frac{1}{2}$-inch Gregorian Reflecting Telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

,, 87. A $3\frac{1}{4}$-inch Gregorian Reflecting Telescope with wooden tripod stand.

,, 88. A pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

,, 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

No. 90. An Arabic celestial globe of bronze, not quite 6 inches in diameter.

,, 91. An astronomical time watchcase, by Professor Chevallier.

,, 92. A 2-foot protractor, with two movable arms, and vernier.

,, 93. A beam compass, in box.

,, 94. A 2-foot navigation scale.

,, 95. Stand for testing measures of length. It consists of two T-shaped gun-metal bars $5\frac{1}{2}$ feet long, to which are fitted two micrometers mounted with adjusting screws for level and position.

,, 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.

,, 97. A 12-cell Leclanché battery.

Instruments Nos. 96 and 97 were purchased by Mr. Gill out of money contributed by the Society towards the expenses of his expedition to observe the opposition of *Mars*.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.

,, 12. The *Fuller* theodolite, to the Director of the Sydney Observatory.

,, 22. The *Matthew* equatoreal, to Mr. Brett.

,, 72. Two polarimeters, to Mr. Ranyard.

,, 74. Registering spectroscope, with prism, to Mr. Lecky.

,, 76. One 5-prism spectroscope, to Mr. Plummer.

,, 78. The $9\frac{1}{4}$-inch reflector, to Mr. Neison.

From the *Sheepshanks* collection :—

No. 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. Sadler.

,, 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. Birt.

,, 34. (8) Transit instrument, to the Rev. Professor Pritchard.

,, 35. (9) Repeating theodolite, to the Sydney Observatory.

,, 39. (13) 8-inch repeating circle, to Mr. Plummer.

No. 42. (16) Mercury bottle, horizon and roof, to Captain Noble.
,, 43. (17) Hassler's reflecting circle, to Mr. Gill.
,, 69. (43) Telescope, with rock-crystal object-glass, to Dr. Huggins.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Professor Asaph Hall for his discovery and observations of the satellites of *Mars*, and for his determination of their orbits. The President will lay before the Society the grounds upon which the Council have decided upon their award.

The Advowsons of Stone and Hartwell.

In the year 1836 Dr. John Lee, who was then Treasurer of the Royal Astronomical Society, executed a deed of gift by which he conveyed to the Society the advowson of Hartwell, and in 1844, by another deed of gift, he conveyed the advowson of Stone to the Society.

Shortly before the date of these deeds his estates had been resettled by Private Act of Parliament, by which the manors of Hartwell and Stone were entailed, leaving Dr. Lee with only a life interest in them. The living of Stone fell vacant in the lifetime of Dr. Lee, and the Society presented Dr. Booth, who held the living until last April, when he died. Soon after the death of Dr. Booth the Council received formal notice that the present lord of the manor of Hartwell, Mr. Edward Lee, intended to dispute the Society's title to both livings, on the ground that they were (in legal language) appendant to the manors, and consequently included in the entail.

The Council, nevertheless, presented the Rev. James Challis, M.A., of Trinity College, Cambridge, who, besides being the son of Professor Challis, a distinguished Fellow of the Society, had many other recommendations. Mr. Lee took steps to dispute the presentation, and the Council employed as their solicitor Mr. Merriman of Austin Friars, who has unusual opportunities of being acquainted with such matters. The result of Mr. Merriman's investigation was that he found that the advowson of Stone had long been severed from the manor, and that the Society's title was good; but that in the case of Hartwell the matter was at least very doubtful. The litigation to establish such a claim, depending on historical inquiries, would be very

costly; and, even if the Society succeeded, it would have to bear a great part of the costs, which could not, according to the rules laid down by the Courts, be recovered from the other side.

It was found that Mr. Lee did not want to present any friend of his own to the vacant living, and was willing to settle the dispute by purchasing, for the sum of £700, the advowson of Stone, subject to the Society's right of presentation to the existing vacancy, and to a release of the Society's claim to Hartwell being included.

The Council having been advised that the sum of £700 was a fair price under the circumstances, entered into a provisional agreement with Mr. Lee for the conveyance and release of all right and claim of the Society to the advowsons of Stone and Hartwell in consideration of the above-mentioned sum, and recommended that the Fellows of the Society should approve and concur in the proposed agreement.

The following resolution was therefore, at the instance of the Council, submitted to the Annual General Meeting held on the 14th of February 1879:—

> "That this Meeting approve and concur in a provisional agreement made between the Council and Mr. Edward Lee for the conveyance and release to Mr. Lee of all the right and claim of the Society to the advowsons of Stone and Hartwell in consideration of the sum of £700."

The Resolution, having been put by the President, was carried unanimously.

Mr. Gill's Expedition for observing the Opposition of Mars.

During the past year the Society has received from Mr. Gill the sum of £250, being the amount granted from the Government Fund of the Royal Society towards the expenses of his Expedition to Ascension.

Up to January 1, 1878, the Royal Astronomical Society had paid £400. 15*s*. 6*d*. towards the expenses of the Expedition; and during the past year a further sum of £99. 4*s*. 6*d*. has been paid to Mr. Gill, completing the sum guaranteed to him. Thus the Government Fund of the Royal Society and the Royal Astronomical Society have so far contributed equally to the expenses of the Expedition.

Mr. Gill, since his return from Ascension, has been busily engaged in reducing the observations made for the purpose of determining the solar parallax. A detailed report of the progress made in the reductions is given in the *Monthly*

Notices for December last (vol. xxxix., p. 51). Mr. Gill has received most important aid towards perfecting his work in the energetic co-operation of fourteen of the principal Observatories. From twelve of these he has received results of meridian observations of the *Mars* comparison stars, and in the *Monthly Notices* for January (vol. xxxix., p. 98) he has published a preliminary discussion of these results. Since that time he has also received a valuable series of results from Professor Lewis Boss, of the Dudley Observatory, Albany, U.S.

The discussion indicates the existence of considerable systematic discordances in the Right Ascensions obtained at the various Observatories, discordances three times greater than could be accounted for by systematic differences in the R.A. of the clock stars employed. These discordances have in part been traced to a personality or habit of observing, which is different for stars of different magnitude; but, besides this, there is a strong suspicion of systematic instrumental error at some of the Observatories. A circular has been issued with a request for further observations, and Mr. Gill is now engaged in discussing the heliometric triangulation of the stars. He hopes, as the result of these discussions, and by aid of the additional observations kindly promised, not only to obtain much information as to the cause of the discordances above referred to, but also to arrive at final places of the comparison stars of such high accuracy that they may be considered absolutely known in the final reduction of the *Mars* observations.

The greater part of the tabular distances of *Mars* from the comparison stars have been computed (employing approximate places of the comparison stars), so that, when the final star places have been arrived at, comparatively little time will be required for the formation of the final equations and their discussion.

The results of observations of α_1 and α_2 *Centauri* at Ascension have been published in the *Monthly Notices* (vol. xxxix., p. 126). Subsequent observations at Melbourne prove that these Ascension observations were made near the time of closest approach of the components of this interesting binary.

The observations in connection with the Expedition which have not yet been reduced are—

1. Moon culminations observed with the transit instrument.
2. Lunar distances measured with the heliometer from the Moon's limbs and from the lunar spot *Hypatia* B.
3. Measures of distance of the spot *Hypatia* B from the Moon's limb along known position-angles.
4. Measures of the diameters of *Mars* and *Saturn*.
5. Measures of the distance of *Mars* and *Saturn* near conjunction, Nov. 1, 2, 3, 4, and 5.
6. Measures of ε *Indi* from neighbouring stars.
7. Measures of *Melpomene* from comparison stars.

The discussions not yet begun are—

1. Deduction of longitude from (1), (2), and (3).
2. Discussion of the merits of the method of employing a lunar spot for longitude operations, and for determining the lunar parallax by the heliometer-diurnal method, with the data of (2) and (3).
3. Discussion of the employment of a similar method for future determination of the parallactic inequality.
4. Discussion of the tabular errors of *Melpomene*—the want of sufficient morning observations rendering a satisfactory discussion of the parallax impossible.

The completion of all the work still involves much labour, but no effort will be spared to lay the whole before the Society as soon as possible. Mr. Gill hopes to be able to present the determination of the solar parallax from *Mars* to the Fellows, in the shape of a volume of the *Memoirs*, before next winter session.

The Library.

The Council are glad to be able to report that the number of books taken out of the Library during the past year is more than 20 per cent. in excess of the number taken out during any former year, and the number of persons using the Library for purposes of reference has also considerably increased. The binding of the Society's books has been systematically proceeded with. 1,062 volumes have been bound in a substantial manner at a cost of £108. 15*s.* 10*d.*, and 343 volumes have been purchased from the Turnor Fund at a cost of £73.

The Library Committee also have pleasure in being able to report that during the past year they have completed the Society's series of the *Astronomische Nachrichten* at a comparatively trifling cost. It would be well if the Society possessed two copies of this valuable astronomical publication, one for reference in the library and the other for loan. The Society already (thanks to the gift of Miss Sheepshanks) possesses the first forty volumes in duplicate. These are the rarest part of the series, and there are also duplicate copies of several of the later volumes. During the past year the Library Committee have completed the Society's set of the *Sitzungberichte* of the Vienna Academy, and have also nearly made up their set of the *Berliner Jahrbuch*; the only missing volumes now being those for 1843 and 1861. The Committee are particularly anxious to complete the Society's set of the *Connaissance des Temps*, the first volume

of which was published in 1679. The Society's set commences in 1810; only a few odd volumes of the earlier part of the series are in the Library.

Amongst the presents to the Society's Library during the past year, a volume containing nearly a complete set of Mitchel's *Sidereal Messenger*, which was presented to the Society by Mr. Burnham—should especially be mentioned. As far as the Council are aware, this appears to be the only set of the *Sidereal Messenger* in England. The cataloguing of the Society's books has been commenced and is progressing. The Council hope that the work will be completed in the course of the present year.

Publications of the Society.

Vol. XLI. of the *Memoirs* has been somewhat delayed in consequence of Mr. Ranyard's visit to America. It was hoped that it would have been published during the past session; but the Council are glad to be able to report that the last chapter is now in the hands of the printers.

Vol. XLIV. of the *Memoirs* is also in the hands of the printers, and will shortly appear. It contains the following Papers:—

Mr. E. Neison. 'On a General Method of Treating the Lunar Theory.'

Mr. N. E. Green. 'Observations of *Mars* at Madeira, August and September 1877.'

Mr. Maxwell Hall. 'Opposition of *Mars* 1877.'

Mr. S. W. Burnham. 'Double Star Observations made in 1877–78 at Chicago with the 18½-inch Refractor of the Dearborn Observatory.'

The volume of the *Monthly Notices* which has appeared during the past year contains some valuable Papers by American and Continental Astronomers. The Council hope that the communication between English and Foreign Astronomers in the publications of the Society will continue to increase; but they take this opportunity of mentioning that some of the papers which have been received by the Society have not been printed, on account of their having been previously published abroad.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year :—

Fellows :—Captain L. C. Bailey.
E. B. Beaumont.
Joseph Bonomi.
Rev. J. Booth.
John Carter.
W. R. Cooper.
S. M. Drach.*
H. S. Ellis.
Rev. C. Gribble.
Rev. P. Holmes.
Henry Johnson.
Rev. R. Main.
John Matheson.
Henry Mugridge.
J. W. Nichol.
G. G. G. F. Pigott.
G. V. Vernon.
Sir A. S. Waugh.

Associate :—Padre A. Secchi.

Joseph Bonomi was born on October 9, 1796, at 76 Great Titchfield Street, in the parish of Marylebone. His father was by birth an Italian, and an architect by profession. He had been for some time the architect of St. Peter's at Rome, but had been induced by James and Robert Adams, the well-known architects of the period, to leave Rome and come to London, where he remained for a considerable time in their employment. He married Rosa Florini, a cousin of Angelica Kauffman, and after his marriage returned to Rome, seemingly with the intention of carrying on his profession there; but the death of her child so distressed the mother that they again returned to England, where Bonomi commenced work and was very successful in its practice. The Sardinian chapel and Montagu House, in London, are from his designs; also Eastwell House, in Kent, now the property of the Duke of Edinburgh; Roseneath, on the Clyde, a mansion belonging to the Duke of Argyle; and many well-known country seats. The elder Bonomi died in the house in Great Titchfield Street, on March 9, 1808. His wife survived him until June 1812. He left four sons. James was killed at the battle of Assaye, 1803. Charles, also in the army,

* An obituary notice of Mr. Drach will appear in the next Annual Report.

died in 1843. The eldest, Ignatius, followed his father's profession, and died in 1870. The subject of this notice, Joseph, had a twin sister and two other sisters; and these complete the family circle. His parents were Roman Catholics and foreigners, yet Mr. Bonomi's education and ideas were thoroughly English. Art influences began very early to associate themselves with him; we have an illustration of this at the baptism of the twins, which took place in the Venetian Chapel when they were only four days old. The sponsors were Dom. John Charles Bonomi and Angelica Kauffman: they were not present, but were represented by Dom. Bartholomeo Ruspoli, military knight, and Maria Cosway. The celebrated patriot, General Paoli, was his sponsor at his first communion.

Joseph Bonomi was chiefly educated at a school in Carshalton, Surrey; after which he became a student of the Royal Academy, and gained the silver medal for the best drawing from the antique, and also for the best model from the antique in sculpture. Sculpture was the branch of art which he took to, and to carry it out he was placed with Nollekens, the sculptor.

In 1823 he went to Rome to continue his studies, and there made the acquaintance of Gibson, a friendship which only ceased with life.

In 1824 he left Rome, and went with Robert Hay, a naval officer, to Egypt, where he remained a number of years, working with Mr Arundale and others for Mr. Hay.

While at Medinet Habou in October 1825, he mentions in his journal the arrival of his friend Burton.

At the end of 1826 he left Mr. Hay and returned to Cairo, where Burton was making plans of the Pyramids and tombs.

In 1828 he accepted an engagement to assist Burton with drawings on the stone for his "Excerpta Hieroglyphica." This work they continued together for some time.

In 1829 he made another journey up the Nile on his own account, and revised his copies of the inscriptions &c.

In October 1829 he commenced a journey to Dongola, which he reached in November and left in December.

In 1831 he again went up the Nile and accompanied Linant in his expedition to the gold-mines in the Desert between the Nile and the Red Sea. They returned to Cairo at the end of the year. Next year Bonomi paid his long desired visit to Bishereen Desert, where he remained about two months.

In 1832–3 he was again working for Hay, and returned to Cairo. At the end of August he, with Catherwood and Arundale, took leave of their friends and started for Sinai and the Holy Land. Bonomi visited the ancient temple and remains at Sarabat el Khadem. He copied many of the inscriptions on the Gebel, crossed the Wady Mokattcb and the Wady Fairan, and reached Sarabat on September 9. Of the Egyptian temple he made a plan, with measurements. In the same month he rejoined his companions at the Convent on Mount Sinai; and on

the 22nd the whole party started for Gaza. They entered Jerusalem on October 9. Bonomi, having adopted the Mahometan dress, and completely identified himself with the manners and habits of the people, managed to enter the Haram es-Sherif; he was followed by Arundale and Catherwood, and they managed to take plans of the buildings as well as sketches (*see* "Quarterly Statement of Palestine Exploration Fund," January 1879).

In 1834 he was still travelling in Syria, and remained some time at Damascus and Baalbeck. At the end of 1834 he returned to England.

A considerable portion of 1835–6 was passed in the north of England and Scotland. While in Yorkshire, Bonomi executed several works in sculpture. Much of the next two years appears to have been occupied with work connected with his Egyptian travels.

In 1838 he was in Rome, measuring and copying the hieroglyphs on the obelisks, and was in England again during the same year. In 1839 he was working for the British Museum. In 1840 and 1841 he was still in London, engaged on the illustrations of Wilkinson's "Manners and Customs of the Ancient Egyptians." In 1841 he was also engaged, with Birch and Arundale, in bringing out a book called the "Gallery of Antiquities."

In 1842 he went again to Egypt, at two days' notice, with the Prussian Expedition. Having accidentally met the members of the party—the Crown Prince of Prussia, now Emperor of Germany, Humboldt, Bunsen, and Lepsius—at the British Museum, at that time on their way to Southampton to take steamer for Egypt, the idea that his former experience would be useful led to the suggestion that he should go with the party. They left Southampton on the 1st of September. Bonomi did not return to England until September 1844.

In September 1845 he married Jessie, daughter of John Martin, the celebrated painter, by whom he left issue.

In 1849 or 1850 he furnished the drawings and, in conjunction with Warren and Fahey, he painted a panorama of the Nile, which was exhibited with considerable success in London and the provinces. It afterwards went to America.

In 1853 he assisted Owen Jones in the works of the Crystal Palace Egyptian Gallery.

In 1860 he left England with the "Himalaya" Expedition to Spain to observe the total solar eclipse of July 18 from Miranda de Ebro. (See *Monthly Notices*, vol. xxi., p. 1.)

In 1861 he was appointed, by the Royal Academy, Curator of Sir John Soane's Museum, in Lincoln's Inn Fields, a position which he occupied till his death, on March 3, 1878, at "The Camels," his own residence at Wimbledon Park.

During the year 1867 the Hieroglyphic Dictionary of Dr. Birch was published by Longmans, in the 5th volume of Bunsen's

"Egypt's Place in Universal History." The hieroglyphic type for this work was cast by Mr. Branston, from designs drawn by Bonomi, and was at that time the only fount of the kind in England.

As an artist of hieroglyphics and Egyptian sculptures &c., Mr. Bonomi has never been equalled.

His principal works are:—Nineveh and its Palaces; Papers to the Society of Biblical Archæology, Royal Society of Literature, Syro-Egyptian Society, &c. &c.; numerous works in conjunction with Mr. Samuel Sharpe; Catalogues of Egyptian Collections—for example, Dr. Abbott's, The Hay Collection, Sir Charles Nicholson's, Hartwell Museum, &c. &c.

The work of which he himself thought most was a complete transcript of the Vignettes and Hieroglyphics upon the Sarcophagus of Seti I., called Belzoni's Sarcophagus, and preserved in the Soane Museum. It was published in nineteen lithographic plates, with an introduction by Samuel Sharpe, London, Longmans, 4to., 1864, under the title of "The Alabaster Sarcophagus of Ormenepthah I., King of Egypt." The above facts are derived from a memoir of Mr. Bonomi prepared by Mr. W. Simpson for the Society of Biblical Archæology, and we are indebted for them to the kindness of Mr. W. Harry Rylands.

Mr. Bonomi was elected a Fellow of the Royal Astronomical Society on February 8, 1861.

James Booth, LL.D., F.R.S., was born at Lava, county Leitrim, on August 25, 1806. He entered Trinity College, Dublin, in 1825, and was elected scholar in 1829. He graduated B.A. in 1832, M.A. in 1840, and LL.D. in 1842. In 1834 he received Bishop Berkeley's gold medal for Greek. He was a candidate for a fellowship, and in 1835 was placed second among the unsuccessful candidates, in 1837 first, in 1838 fourth, in 1839 first, and in 1840 second, receiving a premium on each occasion, and the Madden premium in 1837 and 1839, when he was first.

In 1840 the four candidates who received premiums were George Salmon, James Booth, William Roberts, and Michael Roberts, all well-known mathematicians. Dr. Salmon and Mr. William Roberts were elected Fellows in 1841, and Mr. Michael Roberts was elected in 1843, but Dr. Booth does not appear to have become a candidate again. Having thus so narrowly failed to obtain a Fellowship, Dr. Booth left Ireland in 1840, and in the same year was appointed Principal of Bristol College, an office which he held till 1843. Among his colleagues at Bristol were Mr. F. W. Newman, who was professor of classics, and Dr. W. B. Carpenter, who was professor of natural philosophy and natural history. Dr. Booth was ordained deacon by the Bishop of Exeter in 1842, and priest in the same year, by the Archbishop of Canterbury. In 1843 he was appointed Vice-principal of the Collegiate Institution, Liverpool. He

held this position till 1848, when he came to London, and was engaged in writing educational works and lecturing for the Society of Arts. In 1854 he was appointed to the sole charge of St. Anne's, Wandsworth, and in 1859 was presented to the vicarage of Stone, Buckinghamshire, by the Royal Astronomical Society. This living he held till his death, which took place on April 15, 1878. He was also chaplain to the Marquis of Lansdowne for twenty years. In 1864 he was appointed a Justice of the Peace for Buckinghamshire. He married Mary, daughter of Daniel Watney, Esq., of Wandsworth, who died in 1874. Dr. Booth leaves two sons and one daughter; and his sister Maria, who always lived with him, survives him.

Dr. Booth's writings were chiefly mathematical and educational. The former show him to have been an able and original mathematician, and the latter exercised considerable influence on the promotion of education among the middle and industrial classes.

His earliest printed paper appeared in the *Philosophical Magazine* for 1840, under the title "On the Focal Properties of Surfaces of the Second Order"; but before this he must have devoted considerable time to his method of tangential coordinates by which his name is best known to mathematicians. This method was published in 1843, in an octavo tract of 32 pages, entitled "On the Application of a New Analytic Method to the Theory of Curves and Curved Surfaces," the pages being headed "On Tangential Coordinates." The preface is dated March 25, 1840,* but the date on the title-page is 1843 and the author is described as "Professor of Mathematics in the Collegiate Institution, Liverpool." The method is not the same as that generally known by the name of tangential coordinates, viz. in which the position of a line is fixed by the perpendiculars let fall upon it from three fixed points, or, more conveniently, by the ratios of these perpendiculars, for in Dr. Booth's system the coordinates of a line are the reciprocals of the intercepts on two fixed axes. Thus, the ordinary equation of a straight line in Cartesian coordinates is $\frac{x}{a}+\frac{y}{b}=1$: if now we fix the point (x, y) and let a, b vary, this point may be regarded as determined by the same equation. Putting $\xi=\frac{1}{a}$, $v=\frac{1}{b}$, the equation becomes $x\xi+yv=1$; and, ξ, v being the variables, this is the tangential equation of the point (x, y) in Dr. Booth's form; while, if x, y be variables, the equation denotes the straight line whose intercepts on the axes are $\frac{1}{\xi}$ and $\frac{1}{v}$. It is this duality of interpretation which is of capital importance; of more importance, indeed, than the invention of the new system of coordinates.

* This date would seem to imply that the tract was originally printed in 1840; but there is nothing else in the 1843 copies to indicate a previous edition, and we have seen no copy of earlier date.

Professor Cayley, in the first chapter of the second edition (1873) of Salmon's *Higher Plane Curves*, writes in reference to line coordinates in general: "There is little occasion for any explicit use of line coordinates: but the theory is very important; it serves in fact to show that in demonstrating by point coordinates any descriptive theorem whatever, we demonstrate the correlative theorem deducible from it by the theory of reciprocal polars (or that of geometrical duality): viz., we do not demonstrate the first theorem and deduce from it the other, but we do at one and the same time demonstrate the two theorems: our (x, y, z) instead of meaning point coordinates may mean line coordinates, and the demonstration is in every step thereof a demonstration of the correlative theorem."

The ξ and ν tangential coordinates invented by Dr. Booth have been sometimes referred to in England as Boothian coordinates; but in point of fact they had been introduced by Plücker as early as 1830, in a paper, "Ueber eine neue Art, in der analytischen Geometrie Puncte und Curven durch Gleichungen darzustellen" (*Crelle's Journal*, t. vi., pp. 107–146). Plücker considers a straight line $Ay+Bx+C=0$, where A, B, C are connected by an equation $aA+bB+cC=0$, a, b, c being constants. The straight line then always passes through the point given by $cy-a=0$, $cx-b=0$. Treating A, B, C as variables, and denoting them by u, v, w, he regards the equation $au+bv+cw=0$ as representing the point $\left(\frac{b}{c}, \frac{a}{c}\right)$.

If the equation be written in the form $\frac{a}{c}\cdot\frac{u}{w}+\frac{b}{c}\cdot\frac{v}{w}+1=0$, this becomes identical with Dr. Booth's system on taking $w=-1$. There is no question therefore that the Boothian tangential coordinates are really due to Plücker. Dr. Booth's discovery was a perfectly independent one; and his system differs from Plücker's in one detail, viz. the equations are not homogeneous. Dr. Booth seems to have been led to his system of coordinates by the "anomalous fact in the application of algebraic analysis to geometrical investigations, that while the locus of a point could be found from the simplest and most elementary considerations, the envelope of a right line or plane could be determined only by the aid of principles, artificial and obscure, derived from a higher department of analysis" (*Tangential Coordinates*, 1843, p. 1).

The Plückerian or Boothian coordinates may be said to stand in the same relation to three-point tangential coordinates (in which perpendiculars are let fall from three fixed points) as Cartesian coordinates stand to trilinear; for in the latter case one side of the triangle of reference and in the former case two of the points of reference move off to infinity. The connexion is exhibited in the first chapter of Salmon's *Higher Plane Curves* (first edition, pp. 13, 14, and second edition, p. 9). Dr. Booth's original tract contained only 32 pages, but he continued to develope the subject

and in his *Treatise on some New Geometrical Methods* (1873) more than 200 pages are devoted to this method of tangential coordinates, a good many examples being included. A number of questions have in recent years appeared in the *Educational Times*, which have been worked out by this system of coordinates, and some of these are reprinted at the end of the second volume of *New Geometrical Methods* (1877), pp. 424–440. It has been thought desirable to enter thus fully into the subject of tangential coordinates because it is in connexion with this field of research that Dr. Booth's name is most familiar to mathematicians, and also because, although he was anticipated by Plücker,* the independent discovery by Dr. Booth of the analytical equivalent to the geometrical theory of reciprocal polars is not without historical interest.

Next to tangential coordinates and reciprocal polars, the subject on which Dr. Booth's writings are most considerable and important is that of elliptic integrals, especially in connexion with the motion of a rigid body round a fixed point. His memoirs "On the Geometrical Properties of Elliptic Integrals" were published in the *Philosophical Transactions* for 1852 and 1854, and his papers on the motion of a rigid body round a fixed point appeared in the *Philosophical Magazine* and other journals. In these researches the author confines himself to the elliptic *integrals* of Legendre, and does not employ the elliptic *functions* —inverse to the integrals—introduced by Abel and Jacobi; and while he was thus perhaps hindered from carrying his investigations as far as he might otherwise have done, the same reason has probably prevented his writings from being much studied. But however this may be, Dr. Booth's papers certainly represent a great amount of very valuable and original research.

In relation to this subject should also be mentioned his memoir "On the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms," which was printed *in extenso* in the *British Association Report* for 1856. The memoir relates to elliptic integrals in the case in which the modulus is unity. In elliptic functions if the modulus k be put equal to zero, the theory becomes identical with circular trigonometry, and if k be put equal to unity, the theory becomes that of parabolic trigonometry. The length of an arc of a parabola, of latus rectum $4m$, measured from the vertex, $= m \sec\theta \tan\theta + m\int \sec\theta\, d\theta$; and, in the case of $k = 1$, the first elliptic integral

* Dr. Klein states (*Fortschritte der Mathematik*, t. ii., 1870, p. 453) that in the second volume of his *Analytisch-geometrischen Entwickelungen* (1831) Plücker has also employed tangential coordinates, and he adds that, although tangential coordinates were first introduced by Plücker in the paper in the sixth volume of *Crelle* cited above, the idea of representing a straight line by coordinates was made use of by Möbius in his *Barycentrische Calcul* of 1827. See also Salmon's *Conics* (5th Edit., 1869), p. 266.

$$= \mathrm{F}(\phi) = \int \frac{d\phi}{\cos\phi} = \log\tan\left(\frac{1}{4}\pi + \frac{1}{2}\phi\right).$$

Dr. Booth's notation is peculiar: he introduces the symbols $\perp$ and $\top$ (which have some resemblance in their mode of application to $+$ and $-$), defined by the equations

$$\tan(\phi \perp \chi) = \tan\phi \sec\chi + \tan\chi \sec\phi,$$
$$\tan(\phi \top \chi) = \tan\phi \sec\chi - \tan\chi \sec\phi.$$

In the case of $k = 1$ we have in Elliptic Functions

$$\tan \mathrm{am}(u+v) = \tan \mathrm{am}\, u \sec \mathrm{am}\, v + \tan \mathrm{am}\, v \sec \mathrm{am}\, u;$$

so that if $\phi = \mathrm{am}\, u$, $\chi = \mathrm{am}\, v$, then $\phi \perp \chi = \mathrm{am}(u+v)$ viz.

$$\left.\begin{aligned} \phi \perp \chi &= \mathrm{am}(\mathrm{am}^{-1}\phi + \mathrm{am}^{-1}\chi) \\ \phi \top \chi &= \mathrm{am}(\mathrm{am}^{-1}\phi - \mathrm{am}^{-1}\chi) \end{aligned}\right\} (\mathrm{mod}\ \ ).$$

The theory thus belongs to the particular case $k = 1$ of Elliptic Functions, studied by Gudermann, and for which the amplitude becomes the function termed by Professor Cayley the gudermannian, and written by him gd u (Cayley's *Elliptic Functions*, p.56). Dr. Booth's trigonometry of the parabola is thus a geometrical illustration of the theory of the gudermannian.

Dr. Booth republished the whole of his mathematical writings, with considerable additions, in two volumes, entitled *A Treatise on some New Geometrical Methods.* This work is dedicated to the President and Council of the Royal Astronomical Society. The first volume, which relates chiefly to tangential coordinates and reciprocal polars, was published in 1873; the second, which appeared in 1877, contains the papers on elliptic integrals, and there is also a treatise on the conic sections, each property being obtained directly from the cone, which is here printed for the first time, although the substance of it was communicated to the Royal Irish Academy as long ago as 1837. In the introduction to this work the author writes, "It has been to me a heavy drawback and deep discouragement that I have had no fellow workers to share in these researches. Neither have I entered into the labours of any. Without sympathy and without help I have worked upon those monographs presented to the public." The English mathematician who devotes himself to one or two special subjects can scarcely expect to have many fellow workers among his countrymen, but the theories to which Dr. Booth's writings relate have been enormously developed on the Continent in the last fifty years, and the comparative neglect to which he alludes may be traced to the fact that it is these foreign researches which, being expressed in more modern forms, have been generally referred to. For example, the investigations of Jacobi and those who have fol-

lowed him on the motion of a rigid body round a fixed point, in which the theta functions are employed, are naturally better known than that of Dr. Booth, in which only the integrals appear.

In 1846, when at Liverpool, Dr. Booth published a tract of 108 pages on *Education and Educational Institutions considered with reference to the Industrial Professions and the Present Aspect of Society*, and also, in the same year, an Address to the Literary and Philosophical Society of Liverpool, of which he was President. He also published in 1847 *Examination the Province of the State; or, the Outlines of a Practical System for the Extension of National Education* (pp. 73), which attracted a good deal of attention. Dr. Booth was treasurer and chairman of the Council of the Society of Arts from 1855 to 1857, and during this period he delivered many lectures relating to education, some of which were printed as pamphlets. Several of his addresses were published by the Society of Arts under the titles *Systematic Instruction and Periodical Examination* (1857) and *How to Learn and What to Learn* (1857), and the latter went through several editions very rapidly. Dr. Booth also edited, and wrote the introduction to, the volume of the *Speeches and Addresses of His Royal Highness The Prince Albert* which was published by the Society of Arts in 1857. By his lectures and writings, as well as by his influence as Chairman of the Council, Dr. Booth may almost be said to have founded the Society of Arts' system of examinations. It is true that examinations had been held in 1854 and 1855, but very few candidates had presented themselves. In 1856, the first year in which Dr. Booth's plan was adopted, there were 52 candidates, the examination being held only in London, and in 1857, when the examinations were held at London and Huddersfield, there were above 200 candidates. Dr. Booth retired from the Council of the Society in 1857 in consequence of a difference of opinion between himself and the Council, the main point in dispute being as to whether the examinations should be partly oral, as Dr. Booth desired, or should be conducted wholly by printed papers, as proposed by Mr. Harry Chester, of the Privy Council Office, and adopted by the Council. It should be remembered that at this time the Oxford and Cambridge local examinations had not been founded, and the only public examination open to the middle and industrial classes was that of the College of Preceptors.

As a preacher Dr. Booth was eloquent, and when minister of St. Anne's, Wandsworth, attracted large congregations. When in 1859 the vicarage of Stone, the advowson of which had been given to the Royal Astronomical Society by Dr. Lee in 1844, became vacant, it was felt that Dr. Booth's services to science and to education gave him a strong claim to the appointment, and although not then a Fellow of the Society, he was (with the full approbation of Dr. Lee, who was a member of Council at the time) presented to the living, in which he succeeded the late Rev. Joseph Bancroft Reade, F.R.S., well known in connexion

with the early history of photography, microscopy, &c. Among Dr. Booth's theological writings may be mentioned *The Bible and its Interpreters* (1861), *A Sermon on the Death of Admiral W. H. Smyth, D.C.L., F.R.S.* (1865), and *The Lord's Supper, a Feast after Sacrifice* (1870). Dr. Booth was elected a Fellow of the Royal Society on January 22, 1846, and of the Royal Astronomical Society on June 10, 1859.

J. W. L. G.

Mr. W. R. Cooper was born in 1843. He was for many years assistant curator, under the late Mr. Joseph Bonomi, of Sir John Soane's Museum in Lincoln's Inn Fields. Here he imbibed an enthusiastic love of archæological studies, and became acquainted with others interested in similar subjects. On the formation of the Society of Biblical Archæology he was chosen as secretary, an office which he retained till his death. In this capacity he greatly assisted the late Mr. George Smith in bringing his discoveries before the public. He also had a large share in editing the valuable series of volumes entitled *Records of the Past.* Besides these semiofficial duties he published several works of his own, amongst which should be mentioned *The Serpent Myth, The Myths of the Horus and Osiris, Egypt and the Pentateuch, Egyptian Obelisks, Heroines of the Past,* and particularly his large and important *Archaic Dictionary.* Mr. Cooper was elected a Fellow of the Royal Astronomical Society in January, 1875. During the last two years his health rapidly failed, and he was obliged to remove permanently to Ventnor, where he died on November 15, 1878.

Henry Samuel Ellis, of Exeter, died on May 13, 1878, in the fifty-third year of his age, at Holmwood, the seat of J. J. Barrow, Esq., Tunbridge Wells, where he was on a visit for a few days; the cause of his death being disease of the heart. In early life he had a taste for scientific pursuits, and took some interest in botany. In a quiet and unassuming manner he made his influence felt in any undertaking in which he was engaged; and he was mainly instrumental in altering the time in Exeter and throughout the West of England, from Bath westward, from local to Greenwich time. In support of all scientific movements in Exeter, Mr. Ellis was most earnest. It was chiefly through his exertions that the British Archæological Association was brought to Exeter; he actively assisted in establishing the free library and museum in that city, and was one of the first to support the local School of Science. Mr. Ellis was mayor of Exeter in 1869, when the meeting of the British Association was held there, and many will remember how admirably he carried out the duties of his office. For many years he regularly attended the meetings of the British Association, and it was this fact, in connexion with the interest

he manifested in aiding to bring the Association to Exeter, that induced the Town Council to elect him an alderman, in order that he might be mayor when the Association visited the city.

Mr. Ellis gave much time and attention to railway business. He was the prime mover, if not the originator, of the Railway Shareholders' Association, and at the time of his death he was chairman of two railway companies, the Culm Valley and the Brixham, and director of many others. He was a director of the Bristol and Exeter Railway until its purchase by the Great Western Railway Company.

Mr. Ellis was elected a Fellow of the Royal Astronomical Society on February 9, 1855, and was one of the party who went to Spain in the 'Himalaya' to observe the total solar eclipse of 1860, July 18, and landed at Santander (*Monthly Notices*, xxi., p. 1). He leaves a widow, six sons and one daughter.

Dr. Peter Holmes, D.D., was born in the town of Plymouth. In 1837 his father sent him to Oxford, where he obtained his B.A. degree in 1840, his M.A. in 1844, and his D.D. in 1859. He was ordained deacon by the Bishop of Exeter in 1840, and priest in the following year. In December 1841 he was elected a Fellow of the Royal Astronomical Society. He was given the curacy of Sheepstor in 1840, of Bickleigh in 1843, and of Egg Buckland from 1847 to 1861. For seven years he was Diocesan Inspector of Schools in the Deanery of Plymouth, and from 1868 acted as curate at Pennycross. For many years he was the Head Master of the Plymouth Grammar School; and he afterwards carried on a private school at Mannamead. The greater part of his life may be said to have been devoted to education, for which he was eminently qualified. He was a man of high attainments, most genial and warmhearted in manner, and had the merit of winning the love of his pupils, and creating in them a lasting interest in him during their future lives. Dr. Holmes led an active and useful life. His sonorous tones were frequently heard at the Plymouth Institution, over which he had presided as its President, and his portly frame and ready utterances will be sadly missed there. Of late years he generally officiated on Sundays in the services at Pennycross Chapel, and was ready at all times to give cordial assistance to those who sought his aid.

His literary attainments were of the highest order, and the profound and scholarly character of his mind may be judged from a list of his works taken from the *Clerical Directory*: "Observations on the Standard of Doctrine in the Church of England," 1848; "Translation of Bishop Bull's *Defensio Fidei Nicænæ*," 2 vols. for the Anglo-Catholic Library, Oxford, 1851–52; "Translation of Bishop Bull's *Judicium Ecclesiæ Cathol.*," ibid., 1855; "Treatise on Diocesan Synods," 1852; Articles on "Greek Testament Criticism" in the *Christian*

Remembrancer, and also in the third edition of Kitto's *Biblical Cyclopædia*, viz. "Divination," "Ham," "Jesus Christ," "Laws of Moses," and about fifty others, 1860–66; "On the Irish Church Question," 1868; "On the Connection between Church and State," a paper read at a Synod of the Plymouth Deanery; also Tertullian's "Five Books against Marcion," translated for Clark's *Ante-Nicene Christian Library*, Edinburgh, 1866; also Tertullian's "Ad Nationes," in the same series, 1869; Tertullian's "De Præscriptione Hæreticorum," "Adversus Hermogenem," "Adversus Valentinianos," "De Carne Christi," "Adversus Praxean," and other tracts by the same Father, translated for the same series, 1870; "The Anti-Pelagian Works of St. Augustine"; "De Peccatorum Meritis et Remissione"; for Clark's English Edition of St. Augustine's Works, 1871; and fourteen other treatises in 8vo. volumes.

Dr. Holmes was domestic chaplain to the Countess of Rothes. He leaves a widow, but no children.

Henry Johnson resided at 39 Crutched Friars, London, E.C., where he carried on the business of a wine merchant. He was much attached to mechanical pursuits, and erected a workshop at the top of his house, where he constantly employed one or two skilled workmen. He was the inventor of the *Volutor*, an apparatus for describing spirals, which is described in the *British Association Report* for 1869 (Transactions of the Sections, p. 60), and of a deep sea pressure gauge (see *British Association Reports*, Transactions of the Sections, 1859, p. 236, and 1860, p. 202). The object of the latter was to determine the pressure of the water at great depths in the sea by means of the compression of the water contained in the instrument, which may be regarded as a small hydraulic press, of which the ram is forced into the cylinder by the increasing pressure of the sea when sinking, and expelled by the expansion of the water in the cylinder when rising. Both instruments were exhibited in the Exhibition of 1862, and are described in the official report of the Jurors, Class XIII., pp. 16 and 41. Mr. Johnson also exhibited a metallic deep sea thermometer, to be used in experiments with his deep sea pressure gauge, so contrived that the indications of the instrument were not at all liable to be disturbed by the great pressure of the water upon it (*Ibid.* p. 38). He made numerous experiments with the deep sea pressure gauge in comparatively deep water off the Isle of Wight. For six or seven years before his death he had become completely broken down in health, and had resided chiefly at Worthing. Mr. Johnson never married.

The Rev. Robert Main, M.A., F.R.S., was born at Upnor, in Kent, on the 12th of July 1808, and was educated at a

private school of deservedly good repute at that time, which was conducted by a sound mathematician (the Rev. J. Neave), whose memory he always held in great esteem, and to whom he considered himself indebted throughout his after career for the good education he received from him, more especially for the knowledge of Euclid and Algebra beyond what was usually taught in those days. After leaving school he became engaged in tuition as a master in the Grammar School at Bishop's Waltham, Hants (of which the Rev. T. Scard was the head master), where he remained until he left it for Cambridge. In 1831 he entered Queens' College in that University, and after a successful course of study graduated as Sixth Wrangler in 1834. He was shortly afterwards elected to a Fellowship, but did not reside at Cambridge very long, for, on the appointment of Professor (now Sir George) Airy in the year 1835 to succeed Mr. Pond as Astronomer Royal, he was offered and accepted the office of First (or, as it is now called, Chief) Assistant at the Royal Observatory, which necessitated his removal to Greenwich. The published volumes of the Royal Observatory from 1836 to 1860 supply sufficient evidence of the energetic way in which Mr. Main supported the Astronomer Royal in the measures he took to carry on the scientific operations of that establishment. Everyone who has had much to do with large observatories well knows the great value of such support, and it is to Mr. Main's careful superintendence of the observations and subsequent calculations for very nearly a quarter of a century that a considerable part of their accuracy and completeness is due.

But although his application to these duties occupied for so long an interval the principal part of Mr. Main's time, the publications of the Royal Astronomical Society witness that his scientific energy was by no means thus exhausted. He availed himself of every opportunity of utilising the results obtained at Greenwich for the benefit of practical and theoretical astronomy, and we shall notice briefly a few of the applications to which they were, in his hands, thus applied. The first of these, we believe, consists of a series of papers on the correction of the Elements of the Orbit of *Venus*, published in 1837 and 1838, and in which the observations of that planet by Professor Airy, at Cambridge, during the years 1833–35 are made use of for comparison with the *Nautical Almanac* places then derived from Lindenau's Tables, as well as later observations obtained at the Royal Observatory. In 1840 Mr. Main contributed a paper to the Society, "On the present state of our knowledge of the Parallax of the Fixed Stars." Such knowledge was then but small, and till recently much more of a negative than a positive kind; but it is always of great importance that attention should be called to the existing state of a subject in which there is reason to suppose that considerable advances are shortly to be expected, and we need hardly remark that this was then

the case with the problem, so long supposed to be insoluble, of the parallax and distance of the fixed stars. In February 1841 Mr. Main was elected one of the Honorary Secretaries of the Society, and for some years the duties of that office were ably discharged by him, in conjunction, first with Mr. Rothman, and afterwards with Mr. Galloway. On his retirement therefrom in 1846, the Council acknowledged his services in the following words: —"In addition to the zeal in behalf of the Society which has actuated him, in common with others, Mr. Main has brought to the duties of his office a close acquaintance with practical astronomy as well as theoretical, and the habits of order demanded by a daily attention to astronomical duties more onerous than those of our Secretaryship. So heavy, indeed, are these last that the Council acknowledge peculiar obligations to the gentleman who, residing at so great a distance, and pressed by public calls of such magnitude, has for years found time to be the constant superintendent of the routine of our business and a regular attendant at our meetings." In reference to the paper before mentioned on the parallax of the fixed stars, we may quote the words of Sir John Herschel in his speech on giving the Gold Medal of the Society to Professor Bessel in 1841, for his noteworthy success in first obtaining, in the case of 61 *Cygni*, a parallax generally acknowledged to be trustworthy and claiming the acceptance of astronomers. "In whatever reference," he says, "I may have to make to the history of the subject, I must take this opportunity to acknowledge my obligations to the author of this paper, as well as for his exceedingly luminous exposition of the results of those more successful attempts on the problem by Henderson, Struve, and Bessel, which I shall now proceed more especially to consider." And further on—"This is the final and severe test: Mr. Main has applied it, and the results have been placed before you—*oculis subjecta fidelibus*. If all this does not carry conviction along with it, it seems difficult to say what ought to do so."

On resigning the secretaryship, Mr. Main was elected one of the Vice-Presidents of the Society. In 1849 he contributed to the Society a paper on the form of the planet *Saturn*, suggested by Sir William Herschel's conjecture, from repeated estimations, that its figure was not elliptical but "like a parallelogram with the corners rounded off." Mr. Main gives a series of careful measurements with a micrometer in 1848 and 1849, the result, which was confirmed in subsequent papers, appearing to establish the perfect ellipticity of the planet's shape. In 1850 appeared his first paper on the important subject of the proper motion of the fixed stars. The final result of the discussion and determination of the proper motion of all stars contained both in Bessel's *Fundamenta* (formed from Bradley's Greenwich observations) and in Airy's Twelve-Year and Six-Year Star Catalogues are too well known to astronomers to need any detailed description here. The next paper of importance communicated by Mr. Main was published in 1855, and contains an investigation of the

values of the constants of nutation and aberration, and of the parallax of γ *Draconis*, as deduced from the observations made with the twenty-five foot zenith tube at the Royal Observatory, Greenwich. The observations discussed extend from June 1837 to May 1848, and were tolerably continuous throughout that time, the only exceptions being from periods of bad weather and the difficulties of seeing the image of the star well in the daytime, which required a more than usually transparent state of the atmosphere. The instrument, which was superseded, at the end of these observations, by the present reflex zenith tube, was erected by Troughton whilst Mr. Pond was Astronomer Royal; but no regular use, in a way suitable for delicate inquiry, was made of it in Mr. Pond's time. Mr. Main considered that the value deduced of the nutation constant was entitled to considerable weight; that of the annual parallax is negative and therefore inadmissible, though sufficient to prove that the true value was exceedingly small. Mr. Main next published a valuable paper on the apparent diameters of the large planets, from measurements made with Airy's double-image micrometer attached to the East Equatoreal of the Greenwich Observatory. The observations, a large proportion of which had been made by Mr. Main himself, extend over a space of more than twenty years, commencing with the Astronomer Royal's invention of the instrument and its construction in the year 1840. We have already referred to previous papers on the observations made by the author for determining the form and ellipticity of *Saturn*; the present one (published in 1856) is chiefly concerned with the diameters of *Mercury*, *Venus*, *Mars*, and *Jupiter*. In the earlier communications, measurements are included, not merely of the body of *Saturn*, but of the rings and whole system of that planet.

In 1857 Mr. Main turned his attention to the important subject of the value of the constant of refraction, his investigation being derived from zenith distance observations of stars near the north and south horizon made at the Royal Observatory in the years from 1836 to 1854; the result being to modify to some extent the values of the refraction previously used for stars observed at great distances from the zenith. We need hardly remark that this is an element of uncertainty which has always given practical astronomers a great deal of trouble and anxiety.

The time had now arrived when it was felt that some public recognition ought to be made of the value of Mr. Main's various and important labours. Accordingly, in February 1858, the Gold Medal of the Society was awarded to him "for his various contributions to the *Memoirs* of the Society," the duty of presenting it and making the usual address on the occasion being discharged by the President, the late Mr. Johnson, who then was filling the office of Radcliffe Observer at Oxford, in which Mr. Main was himself so soon to succeed him.

In the following year, 1859, Mr. Main was deputed, in con-

sequence of the continued illness of the President, the late Mr. Bishop, to pronounce the annual address on the award of the Gold Medal to Mr. Carrington for his Redhill Catalogue of Circumpolar Stars; and this duty was discharged with much ability. At the same meeting Mr. Main was elected President of the Society, and filled this office for the customary term of two years, during which it fell to his lot to deliver presidential addresses on the presentation of the medal to the great physical astronomer, Professor Hansen, of Gotha, for his Lunar Tables, and to M. Hermann Goldschmidt, of Paris, for his discovery of thirteen small planets and other works in observing astronomy, many of which had been performed with seemingly very inadequate means.

Reference should not be omitted to an interesting paper by Mr. Main, communicated to our *Monthly Notices* for June 1859, "On the Present State of the Controversy respecting the Amount of the Acceleration of the Moon's Mean Motion." It is well known that Dr. Halley appears to have been the first to notice the fact of there being such acceleration, though the state of the lunar theory in his day was not sufficiently advanced to enable him to give even a probable guess as to its magnitude. Laplace partly explained its cause, but subsequent observations showed its amount to be much greater than had been supposed, and Professor Adams came to the conclusion that existing theories were only capable of accounting for a part of the effect actually observed. M. Delaunay also investigated the subject, and obtained a result essentially agreeing with that of Professor Adams, which was, however, disputed by Professor Hansen and other mathematicians. Mr. Main gives, in the paper before us, a careful *résumé* of the discussion, concluding it with the expression of his opinion that, "as far as we can judge from what is before us of the theoretical investigations of all concerned, Adams and Delaunay seem to have right on their side." This view was afterwards generally accepted by astronomers, so that an outstanding discrepancy between theory and observation remained to be explained. A possible cause has been suggested in a retardation of the diurnal motion of the Earth on its axis produced by the friction of the tidal wave, so that the discrepancy would consist, not in a greater acceleration of the Moon's mean motion than that accounted for by theory, but in an alteration of our unit of time in estimating it.

Allusion has already been made to Mr. Main's determination of the value of the constants of aberration and nutation from the observations with the old zenith tube of the Royal Observatory. The result for the former element was too discordant with other values to be considered very satisfactory, and in 1860 Mr. Main made another determination from eight years' observations with the new reflex tube, the simplicity of the construction of which almost removed all causes of dread of error arising from mechanical or instrumental causes. The value of the constant

of aberration thus found was 20″·34, which is entitled to considerable confidence. Mr. Main also made a fresh determination from these observations of the annual parallax of γ *Draconis*. As before, the result was a small negative quantity, proving only that the true value was exceedingly small.

Mr. Main retired from the chair of the Society in February 1861. But before that occurred, an important event in his life had taken place to which reference has already been made. On the 1st of March 1860, Mr. Manuel J. Johnson died, after having devoted nearly twenty years to directing the work of the Radcliffe Observatory. The trustees, in the month of June 1860, nominated Mr. Main to succeed him, and thus terminated his long connection with the Royal Observatory. The Astronomer Royal, in his Report to the Board of Visitors on the 1st of June 1861, expresses himself thus :—"Mr. Main, who had for twenty-five years held the office of First Assistant, and to whose zeal and orderly assiduity and honourable conduct on every occasion the position of the Observatory is in no small degree due, accepted in the last summer the office of Radcliffe Observer at Oxford, and on September 30 resigned his occupation at the Royal Observatory."

The last paper Mr. Main contributed to the Society before his removal to Oxford was one read at the meeting on April 13, 1860, entitled "Remarks on the Controversy respecting the Secular Acceleration of the Moon's Mean Motion." This paper is supplementary to the one on the same subject we have already referred to; deprecating any definite general conclusion on the whole matter before the publication of the theories of Hansen and Delaunay, but contending that there was very great reason to accept the conclusion of Adams and Delaunay, and to believe that "they have given the correct value of the acceleration depending on the diminution of the eccentricity of the Earth's orbit." It was called forth by a paper of Dr. Hartwig, of Schwerin, who had misunderstood Mr. Main's views on the point in consequence of his non-reference to it in the speech on the presentation of the medal to Professor Hansen.

At the meeting on January 11, 1861, he gave from the chair a short account of the proceedings at the Radcliffe Observatory since the decease of Mr. Johnson and his own appointment as Radcliffe Observer, and in the following May he communicated some observations of his own of phenomena of *Jupiter's* satellites made with the telescope of the heliometer at that Observatory. This instrument was constructed by Messrs. Repsold, of Hamburg, and formed a valuable addition to the instrumental equipment of the Radcliffe Observatory. From unavoidable delay in its completion, it was not received at the Observatory until the winter of 1848; a detached building was erected for it the following summer, and in October the instrument was set up under the personal superintendence of Adolph Repsold. The object-glass (made by Merz, of Munich)

has an aperture of $7\frac{1}{2}$ inches and a focal length of 10 feet 6 inches. A great improvement in the meridional observing took place under Mr. Main's directorship through the purchase of the Transit Circle which had been used by Mr. Carrington at Redhill. The diameter of the object-glass of this instrument is 5 inches and its focal length 66 inches. It was removed to Oxford in the summer of 1861, and observations with it commenced in 1862. Mr. Main was soon able to endorse Mr. Carrington's statement as to its excellence; and the meridional instruments previously in use were now superseded for Observatory purposes, being retained, however, in the building for practice, if required, by students of the University.

From the time we have mentioned, almost to that of his decease, Mr. Main continued most assiduously to apply himself to keeping up and extending the reputation of the Radcliffe Observatory; the zeal and diligence with which he did so being sufficiently evidenced in the successive volumes of observations which have punctually and regularly made their appearance year by year.

Not long before Mr. Main's appointment, Mr. Johnson had completed the scheme of star-observation on which he had for some years so usefully employed that part of the resources of the Observatory—the reobservation of the stars of Groombridge's Catalogue, from which much valuable information respecting stellar proper motion &c. has been derived. On its completion he had prepared a list of remarkable stars which he thought it desirable to have carefully reobserved, consisting chiefly of stars of greater magnitude than the third, stars within 6° of the North Pole, and stars possessing physical peculiarities, or having orbital proper motion. This list Mr. Main made it his first care to complete, and he accomplished it by the end of 1861, although the Catalogue containing the observations (reduced to the epoch 1860) could not, owing to the pressure of other work, be published till 1870. The Catalogue in question contains no less than 2,386 stars, and forms the "Second Radcliffe Catalogue," the observations on which it is founded being made from the years 1854 to 1861 inclusive. With 1862, as we have mentioned, commenced the observations with the Carrington Transit Circle; and the first five years of its use were given, as far as star-observing was concerned, to the observations of a large number of stars between the fifth and seventh magnitudes. In 1867 a new working list of stars was prepared, including all the stars in the British Association Catalogue which still required to be oberved, together with others between the sixth and eighth magnitudes found in various Catalogues, chiefly included in celestial zones from 50° to 70° N.P.D. Mr. Main intended to form a Third Radcliffe Catalogue from observations of nearly 4,400 stars made during the nine years ending in 1870; this laborious work was commenced in 1876, but he did not live to complete it.

With regard to planetary meridional observations, Mr. Main

thought it useful to observe continuously the Sun, and the Moon when she passed the meridian before or very soon after midnight, it being too great a tax on the strength of the Observatory to carry the latter on beyond this. During his first years at Oxford he kept up at certain times meridian observations of all the large and some of the small planets; but afterwards he retained only amongst the former the inferior planets, especially *Mercury*, which the shortness of its period and the frequent difficulty of seeing made it more desirable to observe whenever practicable, and of which many valuable observations were made on days when it was not seen elsewhere.

For details of the cometary and phenomenal observations of various kinds out of the meridian we must refer to the printed volumes of *Observations*. The heliometer was employed in measurements of distances of double stars (especially Struve's *Lucidæ*), of planetary diameters, &c.; by far the greatest part of these were made by Mr. Main himself. A series of observations with it, accompanied by delineations, of spots seen on the Sun commenced to be made in the month of November 1874; these, which were chiefly made by one of his assistants, are printed and engraved in the volume for 1875, the last which Mr. Main published, the date of its Introduction being December 14, 1877. His death occurred on May 9, 1878.

Enough has been said to show that the *Radcliffe Observations* have contributed to the general progress of astronomy. The reductions were carefully and rigorously kept up, and in their methods sundry improvements, particularly in the calculation of the occultations, were introduced. Meteorological observations were also regularly carried on; but his multifarious observatory duties by no means exhausted Mr. Main's energies or scientific activity. He published in 1863 a book entitled "Practical and Spherical Astronomy for the use chiefly of Students in the Universities." This work is referred to in the Annual Report of the Council for 1864 as follows: "It is nothing more than an act of simple justice to the merits of Mr. Main's volume to say that it is the first successful attempt in this country to furnish the student not only with the mathematical deductions of astronomical formulæ, but at the same time with the best methods of their practical application in the actual business of an Observatory." Previously to the appearance of this important work, Mr. Main had published a translation of the first part of Brünnow's *Lehrbuch der Sphärischen Astronomie*, which includes the chapters on Parallax, Refraction, Precession, and Nutation, and which, from its acknowledged excellence, he considered might be of service at Cambridge and other Universities in which the mathematical sciences are cultivated.

Mr. Main was elected a Fellow of the Royal Society in 1860, and served for several years on its Council. His last communication to our Society was, we believe, a paper containing observations of the remarkable meteoric shower in November 1866.

Mr. Main's studies were not at all confined to astronomy. He was a most diligent student during his boyhood and during the whole of his life, and consequently his attainments were very varied. In a biography already published in a church periodical called the *National Church*, we are told that his *Modern Philosophic Scepticism Examined*—an elaborate address delivered at the request of the Victoria Institute, at their ninth annual meeting—passed through many editions. Mr. Main was selected to preach before the British Association at Bristol in 1875; and, on leaving Greenwich, he published a volume of sermons (which he had preached while residing there).

His acquaintance with Latin and Greek was sufficient to enable him to derive a pleasure from reading in those ancient languages which throughout his life he frequently indulged. Of modern languages his knowledge was more extensive than that of most scholars of his time. He could read and translate fluently French, Italian, German, Dutch, Spanish, Portuguese, Danish, and Swedish; and this was of immense service to him by enabling him to read the works of foreign astronomers. In 1838 he married the sister of the Rev. Professor Kelland, who was Senior Wrangler in 1834, and has left three sons—Robert, of the Admiralty; Philip, Fellow of St. John's College, Cambridge, who was Sixth Wrangler in 1862; and Francis, M.A., of the Inner Temple. His only surviving brother is the Rev. Thomas J. Main, who was Senior Wrangler in 1838, and for many years head of the Royal Naval College, Portsmouth.

John Matheson was born in Glasgow on the 6th of October 1817. Having completed his education, he proceeded to qualify himself for a commercial life, serving for this purpose with the firm of John Matheson & Co., of which his father was the principal partner. Subsequently he obtained an appointment in the house of William Stirling & Sons, turkey-red dyers, one of the most extensive establishments in the country engaged in that important branch of industry. In this new sphere of exertion he soon exhibited great ability and energy, united with rare business talents, and the result was that, after the lapse of a few years, he attained the position of managing partner, and ultimately became the sole proprietor of the establishment. In 1859 he married Miss Jessie Merry Forrester, daughter of the late Robert Forrester, Esq., of Glasgow.

The career of Mr. Matheson outside the calls of business was distinguished by untiring activity. Although he studiously abstained from taking part in the municipal affairs of his native city, he exhibited a deep interest in public questions, and in every movement having for its object the advancement of the material or social condition of the community amidst which he lived. He spoke and wrote with uncommon clearness and vigour, and the results of a sound discriminating judgment were

apparent in all his thoughts. He acted for several years as Chairman of the Glasgow Chamber of Commerce, and the opinions expressed by him, based as they were upon enlarged and judicious views of the commerce of the country, were always listened to with deference.

While Mr. Matheson took a leading part in all social and philanthropic movements connected with Glasgow, he was at the same time distinguished by a considerable degree of mental culture. In early life he contributed occasionally to the periodical literature of the day. During the latter period of his career he visited India twice, chiefly with the view of acquiring additional knowledge respecting the commerce of that great country, with which he carried on extensive mercantile transactions; and the results of his observations on the occasion of his first visit were published in a work entitled "England to Delhi," which contains much interesting information and picturesque description conveyed in a pleasing style. Mr. Matheson exhibited a deep interest in astronomical studies. He was elected a Fellow of the Royal Astronomical Society in the year 1866. In 1876, when the British Association met at Glasgow, he communicated to the Association a valuable paper on the silver currency, a branch of a subject to which he had devoted much attention. He was President of the Athenæum, a literary and educational Institution of Glasgow, and at the time of his death he was preparing a lecture which he purposed delivering to its members at the commencement of the winter session. He frequently delivered popular lectures on various subjects to the working people of his establishment, which was situated in the Vale of Leven, about twenty miles from Glasgow.

His last public appearance in Glasgow was in connection with a great commercial disaster which had befallen his country, and his friends love to think that he was on that occasion permitted to give one more practical proof of the noble generosity of his nature. His death occurred under circumstances especially painful. He was Chairman of the Glasgow Festival Concerts Committee, and on the evening of November 12, 1878, he was to have presided at the commencement of a series of concerts given by the Glasgow Choral Union, but as he was proceeding from his office to his private house on the same day he was taken ill in one of the thoroughfares of the city, and instantly expired.

Mr. Matheson was endowed with a genial warmth of disposition and a hearty kindliness of manner which endeared him especially to those who had the privilege of his personal acquaintance. His career was one of unceasing public usefulness, and his loss was deplored by multitudes of all classes of society in Glasgow and the Vale of Leven, who retain a lasting remembrance of the many admirable qualities of head and heart by which he was distinguished.

John Walter Nichol was admitted a Fellow of this Society on the 8th of May 1874. He was born at Edinburgh on January 29, 1843. He was the son of Walter Nichol, Doctor of Laws, Teacher of Mathematics in the High School, Edinburgh. Mr. Nichol received his earlier education at the Edinburgh Institution, and subsequently attended lectures at the University of that city. On quitting the University, Mr. Nichol entered the office of a firm of merchants in Leith, in which he remained till he acquired considerable knowledge of mercantile business.

His mind led him to the study of scientific subjects, and specially to that of astronomy; and as he happily had the means available to gratify this taste, he spared neither time nor effort in trying to attain proficiency.

At the close of his curriculum he was engaged by Professor P. Smyth to assist in the reduction of the Edinburgh observations which form the basis of the Catalogue of stars recently published there. Mr. Nichol volunteered his services for the observation of the transit of *Venus* 1874, and accompanied the expedition to the Hawaiian Islands, under Captain Tupman, greatly contributing to the success of the enterprise by his accurate, business-like habits. On returning to England he was entrusted with the reduction of the lunar and meridional observations made at Honolulu; on completing which he proceeded to Germany, and studied his favourite science under Professor Bruhns, of Leipzig, for two years, publishing (*Astron. Nach.* No. 2211), while there, an investigation of the orbit of the third comet of 1877 from the whole of the European observations.

Returning to England, he was suddenly cut off in the prime of life by a pulmonary affection, and died at Teignmouth on November 4, 1878.

His genial and kindly nature, combined with his excessive *bonhomie*, rendered him a pleasant friend, and many of the associates of his earlier youth remember the good, true, and frank spirit with which he was wont to enliven their frequent reunions.

George Granado Graham Foster Pigott, eldest son of the Rev. George Granado Graham Foster Pigott, Rector of Abington Pigotts, Cambridgeshire, was born on May 16, 1835. He was educated at Marlborough College, and served in the Cambridgeshire Militia in 1854. He entered the 48th Foot as ensign in April 1855, and was present with his regiment at the fall of Sebastopol in September of that year. He served with his regiment during part of the Indian Mutiny, and retired from the Army in November 1859. He devoted much time to meteorological pursuits at his native place, Abington Pigotts, till his death, which took place on May 14, 1878. He was elected a Fellow of the Royal Astronomical Society on June 9, 1865. He was a Fellow of the Meteorological Society.

George Venables Vernon was the only son of Mr. John Venables Vernon, of the firm of Vernon and Edge, engravers to calico printers, David Street, Manchester, and was born on October 7, 1831. He went to a school kept by a Mr. Williamson, of Stretford Road, Manchester, and afterwards studied for some years under a private tutor. He had a great liking for scientific pursuits generally, but more especially for meteorology. He was elected a Fellow of the Royal Astronomical Society on January 14, 1853, and in 1861 was elected a member of the Manchester Literary and Philosophical Society. He contributed many papers, chiefly on meteorological subjects, to the *Proceedings* and *Memoirs* of the latter society, and was for several years secretary of its physical and mathematical section. When Mr. Glaisher was organising, in 1848, the system of meteorological observations at different stations over the country, the results of which are published in the Registrar General's Reports, Mr. Vernon expressed his willingness to become an observer, and his observations were made and published regularly from 1849 till nearly the date of his death. He was a Fellow of the Meteorological Society and of the Anthropological Society, and a member of the Meteorological Societies of Scotland and France. He carried on the business of a cotton spinner. In private life Mr. Vernon was genial and kind-hearted, and he was very fond of music and other accomplishments. He had a severe illness—an attack of congestion of the brain—a year or two before his death, from the effects of which he never wholly recovered; he suffered much during the last year of his life, and died suddenly of heart disease on January 11, 1878. He leaves a widow.

Angelo Secchi was born at Emilia, Reggio, on June 29, 1818. He attended the school of the Jesuit College of the district, where he was grounded in Greek and Latin.

At the age of 15 years he entered the Company of Jesus, and after terminating his noviciate at the Collegio Romano, he lectured for a year in Rome on grammar and the rudiments of philology; after which he was sent by his superiors to conduct the classes of physics and mathematics in the College at Loretto, where he distinguished himself by his concise and clear method of teaching.

In 1844 he commenced his theological studies preparatory to entering the Church, and continued these without interruption until he was ordained priest on September 12, 1847.

He remained in Rome, lecturing at the Collegio Romano, till March 1848, when political disturbances having arisen in Italy, he was forced, with the rest of his order, to quit his home and go into exile. With many others he came to England and was sent to the Roman Catholic College at Stonyhurst, where, having nothing better to do, he devoted himself to the study of mathematics, until, on October 24, 1848, with twenty-one of his

companions in misfortune, he sailed from Liverpool, arriving at New York on November 19; thence he proceeded to the Georgetown University near Washington, where, while teaching the elements of natural science, he found time to pursue his favourite studies, working in the College Observatory, then directed by Father Curley.

Professor De Vico having died in London in 1849, Secchi was recalled by the General of the Order to succeed him in the chair of astronomy, and to direct the Observatory of the Collegio Romano.

He left Georgetown on September 21, and came to England, visiting the Royal Observatory, Greenwich, and thence passed on to Paris, re-establishing the broken communications between the Observatories.

He had been but a short time in his new position when he set about the foundation of a new Observatory in the Collegio Romano.

Departing from usual principles, he placed his instruments on the top of one of the massive piers which support the dome of the Church of Sant' Ignazio. The new Observatory was formally opened in 1852, and was speedily provided with an excellent refractor by Merz and a fine sidereal clock by Dent. Aided by the munificence of His Holiness the Pope, he established in the same place a very complete Magnetical Observatory. In the course of his meteorological studies he was led to the construction of his celebrated Meteorograph, an instrument by which automatic registrations of the barometer, thermometer, winds, and rain are made at short intervals of time. One of these was sent to the Paris Exhibition of 1867, and was esteemed so highly that the Emperor Napoleon III. conferred upon Padre Secchi the decoration of the Legion of Honour, and the Emperor of Brazil gave him the Grand Cordon of the Order of the Rose.

Probably Secchi's greatest work was the division of stellar spectra into four great groups or classes, viz.:—

Type 1. In which the hydrogen lines are very marked. To this group belong *Sirius*, *Vega*, *Altair*, *Regulus*, and *Rigel*, and about half the stars in the heavens.

Type 2. In which there are numerous fine dark lines, as in the spectrum of our own Sun, and in *Pollux*, *Arcturus*, *Aldébaran*, *Procyon*, and *α Ursæ Majoris*.

Type 3. In which the spectrum is divided by a system of nebulous bands, which are rather more definite towards the violet end, as, for example, in the spectrum of *α Herculis*.

Type 4. In which the spectrum is divided by broad nebulous bands, very definitely defined on the less refrangible side. To this group belong many of the small deep red stars.

Secchi was the first to point out the characteristic features of these groups. He gave considerable labour to examining and classifying stellar spectra, and published numerous catalogues and lists of star spectra, two of the most important of which are

Catalogo delle stelle di cui si è determinato lo spettro luminoso, published at Paris in 8vo. in 1867, and *Sugli spettri Prismatici delle Stelle Fisse*, published in Rome in 8vo. in 1868.

Secchi published regularly the *Memoria dell' Osservatorio*, and these were supplemented by the *Bulletino meteorologico dell' Osservatorio del Collegio Romano*.

He was employed by the Papal Government in 1854 to execute the measurement of a base line, a full description of which appears in his Memoir, *Sulla Mesura della base Trigonometrica eseguita sulla Via Appia nel* 1854–5.

He was also commissioned by his Government to design and superintend the erection of the lighthouses on the coasts of the States of the Church, and at another time the schemes for the water supply of several Roman towns were confided to his skill and judgment.

In 1860 he was sent to Spain for the observation of the Eclipse of the Sun on July 18. Working in conjunction with Señor Aquilar, of Madrid, he was fortunate enough to obtain four photographs of the corona during the total phase.

In 1862 he proceeded to Paris, where he represented his Government at the International Commission on the Metric System.

On September 20, 1870, with the entrance of the Italian troops into Rome, the Papal civil dominion passed away.

The decrees of the new Government against the Church are a matter of history upon which it is not necessary here to dwell; but it will ever be to the honour of the Administration that arrangements were made by special Acts of Parliament to enable our illustrious Associate to continue to occupy the Observatory, which, under his control, had attained a worldwide fame.

In December of the same year he was sent to Augusta, in Sicily, to observe the Solar Eclipse of December 20.

Early in his scientific career the various great Societies recognised his works and placed his name on the list of their Foreign Associates.

The Royal Society elected him November 20, 1856. He became Associate of our Society in June 1853, and he was also Member of the French Académie des Sciences, and of the Imperial Academy of St. Petersburg.

In Italy he was one of the Società Italiana de XL., and was for some years President of the Accademia dei Nuovi Lincei.

The last few years of his life, feeling that his vital power was slowly ebbing, he abandoned active observations, and devoted himself to study, though always controlling and directing the researches of his valued and indefatigable assistants.

Space forbids the rehearsal of the titles of all Secchi's writings. Up to the year 1863 upwards of 200 Memoirs and papers were contributed by him to various scientific bodies and to journals with which he corresponded.

His larger works, which may be mentioned, are the "Measure-

ment of the Base Line on the Via Appia," to which we have already referred, and

1. *Il Quadro fisico del Sistema Solare.*
2. *L'unità delle forze fisiche*, a work which has gone through two Italian editions and has been translated into French and German.
3. *Le Soleil.* Two French editions; also translated by Schellen into German.
4. *Elementi di Astronomia* (lithographed for the use of his students).
6. *Le Stelle.*
7. *Lezioni di Fisica Terrestre* (for the young).

A month before his death appeared, at Milan, *Le Stelle*, which forms one of a valuable series of Popular Science volumes.

In this work he sums up his work on the Physical Constitution of the Stars, to which he had devoted so great a portion of his career. His last work, *Lezioni di Fisica pei Giovani*, is now in the press.

Early in January 1878 illness forced him to take to the bed from which he was fated never to arise.

Though aided by the first surgeons of the University, science was unable to cope with nature, and terrible disease terminated, at the age of only 59 years and three months, a career which had shed lustre on his country and had added another to the long list of names of which the Jesuits are so justly proud.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories.

Royal Observatory, Greenwich.

Observations of the Sun, Moon, and planets with the Transit Circle, and of the Moon with the Altazimuth, have been made regularly as in past years. Considerable progress has been made in the observation of stars in the working list, and the Annual Catalogue for 1878 is larger than usual, containing about 1,300 stars.

A considerable number of observations of phenomena of *Jupiter's* satellites have been accumulated during the past year, and occultations of stars by the Moon have been observed whenever the state of the sky permitted.

The printing of the *Nine-Year Catalogue of* 2,263 *Stars* was completed last summer and the Catalogue is ready for distribution; but before issuing it to the public, it appeared desirable to compare it in N.P.D. with the two last preceding Catalogues. In the Nine-Year Catalogue a change has been made in three of the elements of reduction, viz. the R – D correction, the mean refractions, and the co-latitude, and the comparison with the two Seven-Year Catalogues shows large systematic differences depending mainly on the diminution of refractions and consequent alteration of co-latitude, introduced at the beginning of 1868. The discussion is not yet finished; but the observations of the Sun at the solstices, and of circumpolar stars, and the comparison of the Cape and Melbourne Catalogues with the First Seven-Year Catalogue made by Mr. Downing, seem to show that the old refractions are sensibly correct and that the N.P.D's. of the Nine-Year Catalogue will require systematic correction. It is proposed to insert this discussion as an appendix to the Introduction, and the issue of the Catalogue has consequently been delayed for a short time.

The spectroscopic work has been interrupted since last May, in order that the reductions of the measures of photographs of the Sun might be pushed forward. The chromosphere was examined on 34 days, on 15 of which no prominences were seen; the search, however, was made under somewhat unfavourable circumstances on 10 of these days. The solar spectrum in the neighbourhood of G has been repeatedly examined

with reference to the existence of bright lines in that region, and on May 31 several photographs of this part of the spectrum were taken. The results have been communicated to the Society. The spectroscopic determination of star motions in the line of sight has been continued, and measures of the displacement of the lines of hydrogen or magnesium in the spectra of 34 stars have been made; 11 of these had not been previously examined. All of these observations were made with the Half-prism Spectroscope. The spectrum of the eclipsed Moon was examined with the Single-prism Spectroscope on 1878, August 12, and observations of the "rainband" in the sky spectrum were made daily up to June last with a small Half-prism Spectroscope.

During the year 1878 photographs of the Sun were taken on 146 days; on only 29 of these were any spots visible, and on only 44 days groups of faculæ. There has been a marked diminution in the numbers of spots and faculæ as compared with the previous year. The arrears of photographic reductions, which had accumulated since 1873 in consequence of the delay in the construction of the Position Micrometer have now been cleared off. The position angles and distances of spots and faculæ from the Sun's centre, as well as the areas, have been measured in duplicate up to the present time, and the heliographic latitudes and longitudes, and areas in millionths of the Sun's visible hemisphere, have been deduced from them. The copy for press has been prepared, and the complete results for the year 1876 have been printed in the volume of *Greenwich Observations* about to be issued, leaving the results for the years 1874, 1875, 1877, and 1878 to be included in the next volume. The areas as distinct from positions had been already printed for 1874 and 1875 in the corresponding volumes of *Greenwich Observations.*

The serious and prolonged illness of Mr. Lynn has caused a severe pressure on the Observatory during the last ten months, and it has been found necessary to have frequent recourse to the assistance of computers for the ordinary observations. The reductions, however, have not been suffered to fall behind, and they are now in a very forward state. The unusually cloudy weather of the last two months (succeeding a remarkably fine autumn) has materially relieved the pressure on the computing staff. All the current reductions are brought up to the present time, and the Star Ledgers of R.A. and N.P.D. for 1878 are formed.

Astronomers are well aware of the extent and accuracy of the meridional observations in general and of the meridional and extrameridional observations of the Moon in particular, most regularly followed up at the Royal Observatory, and printed in detail in its *Observations.* But they are scarcely aware that the same volumes contain a great mass of separate essays on various trains of observation and other

subjects relating to astronomy, which it is hoped are not without value. The Astronomer Royal has commenced the formation of an Index to these essays, which may bring them more to the notice of the public, and may render them at once accessible to the astronomer's quest.

The Radcliffe Observatory, Oxford.

In May last this Observatory was deprived by death of the services of its eminent and distinguished Director, the Rev. Robert Main.

The Trustees of the institution shortly afterwards placed it under my* temporary control, pending their appointment of a successor to Mr. Main. By a somewhat recent statute of the University, the Savilian Professor of Astronomy is no longer permitted to hold the directorship of the Radcliffe Observatory.

By a remarkable concurrence of events, the second assistant of the Observatory died very soon after his respected chief, and at the same time the first assistant, Mr. Lucas, on account of the infirm state of his health, retired from his office with a handsome pension accorded to him by the Trustees in acknowledgment of his long services. There remained, therefore, on the staff of the Observatory one assistant and one computor only. These, however, have been temporarily supplemented by assistance derived from the resources of the University Observatory.

Mr. Stone, the Director of the Royal Observatory at the Cape of Good Hope, has been appointed to the Radcliffe Observatory, and is expected to arrive in Oxford early in July of the present year. The Radcliffe Trustees, with great liberality and consideration, have allowed Mr. Stone to remain in his present post at the Cape until he shall have satisfactorily completed the great work of a Catalogue of Southern Stars, which for some years past has occupied his attention.

At the suggestion of the Trustees I submitted to the Astronomer Royal and to Professor Adams propositions for the reorganisation of the Observatory, and I am gratified at finding these propositions have met with the approval of these eminently practical authorities. Mr. Stone also has expressed his acquiescence in the plans suggested.

Exactly the same sort of work, and on the same lines as that adopted by Mr. Main, has been carried on at the Observatory so far as the more limited staff has permitted; my chief endeavour being to leave Mr. Stone unfettered in the making of his own arrangements, and in the establishing of his own traditions, and as unincumbered as possible by the accumulation of arrears.

* The above report is written by Professor Pritchard.

The state of the Carrington Transit Circle has occupied much of my anxious attention. From its first erection in Oxford it has been affected with an uncertainty in the determination of the nadir to a far more serious extent than is usual and unavoidable with first-class astronomical instruments. Notwithstanding numerous experiments and devices, I have been unable to ascertain the cause or causes of the discrepancy in question. The instrument had been used for a considerable time by Mr. Carrington at Red Hill. It was transferred from thence to Oxford, and erected in its present position, without the assistance of a professional instrument maker, and it is quite possible that it may have been slightly injured during the removal, or that the brass plates which support the pivots of the instrument may have been insecurely attached to the piers. No doubt it will receive Mr. Stone's earliest attention, and if found to be either too small for present requirements or otherwise inherently defective, the Trustees will probably supply a new and superior instrument.

Oxford University Observatory.

Since the date of the last annual report of this Observatory, the delegates of the Clarendon Press have printed and circulated the first fasciculus of the astronomical observations made here under my direction. I take this opportunity of thanking the many eminent astronomers, both at home and abroad, for the hearty sympathy and encouragement which they have accorded to this first contribution made to the extension of astronomical science in this new institution of the University of Oxford.

In accordance with a remark made in the last annual report, the observation of double stars has been exclusively confined to objects whose well pronounced relative motions and other circumstances present the promise of an accurate determination of their elliptical orbits. A comparison of the observed motions of the components of ξ *Ursæ Majoris*, 70 *Ophiuchi*, μ^2 *Boötis* with those derived from the orbits computed in this Observatory turns out to be highly satisfactory, and more particularly so in the case of ξ *Ursæ*, where the rapid change of positional angle affords a rapid and secure test of the accuracy of the theoretical work.

In the course of the preceding and present winters two sets of measures of 40 of the stars in the *Pleiades* have been completed, and their remeasurements will be continued so long as the stars remain visible during the present apparition of the group. They are with the *duplex micrometer* attached to Mr. Grubb's Refractor. When these observations have been reduced they will be compared with Bessel's celebrated measures of the same stars made with the Königsberg Heliometer in 1838.

A few observations of Tempel's periodical comet have been secured, notwithstanding its low altitude and the brightness of the sky at the time of its apparition. No other observations of this periodical comet appear to have been published in England.

Lunar photography has been prosecuted with the same regularity as heretofore. Mr. De La Rue's magnificent measuring engine arrived at the Observatory in the course of the spring; no time was lost in ascertaining its capabilities, and those of the lunar photographs to the purposes of delicate and accurate measurements, and their applicability to the practical determination of the lunar physical libration. The preliminary examination has occupied much time; but at the present a fair amount of progress has been made in the determination of the selenographical coordinates of Triesuecker (B) and Ptolemy (A); these being the two points selected for the prosecution of this laborious and intricate investigation. In the course of this preliminary work, it seemed that an excellent subsidiary test of the general accuracy of the instrument and of the photographs might be afforded by ascertaining how far both of them were applicable to the determination of the height of lunar formations. The result has been highly satisfactory. The peculiarity of the measuring instrument, and the quiescent nature of a photograph, enables us to dispense with the troublesome and inaccurate reference to the Moon's terminator, and even the lunar cusps, at all times ill defined. The success of this presumably new application of celestial photography affords some substantial hope of still further usefulness of the process.

The intelligent and diligent attention of the two assistants, Mr. Plummer and Mr. Jenkins, to their varied duties in this Observatory demands acknowledgment.

The sub-aerial observatory, completed on the roof of the new lecture room, attracts the curiosity of many of the University students. An instrument for measuring and recording the daily amount of sunshine is placed among the other instruments, and the results are published weekly in an Oxford journal. It excites considerable interest; and if similar records were kept in various districts throughout the country, some important information might be reasonably expected.

Cambridge Observatory, 1878.

The work carried on during this year continues to be of the same character as that of several previous years. A large proportion of the zone stars have now been observed three times and upwards, so that in certain regions it has become requisite to increase the working breadth of the zone, and even with this

advantage the progress of the work is occasionally somewhat slow; the weather, too, has been unfavourable. But, notwithstanding these drawbacks, 3,065 observations of zone stars have been made during the year, and 671 observations of standard stars for clock and instrumental correction, with the necessary observations for collimation and level errors and for nadir points.

The reductions of standard stars are finished up to the end of 1877, both for Right Ascension and North Polar Distance: the reductions for 1878 are in progress. The calculation of the constants used in the reduction of zone stars is completed for 1875 and is well advanced for 1876. The mean Right Ascensions and North Polar Distances of zone stars are computed to the end of 1874, the true Right Ascensions and North Polar Distances to the end of 1875. All the observations up to the present time are entered in the reduction books, and the means of microscopes and wires taken. The Declination Micrometer has been carefully tested, by bisecting the wires in the South Collimating Telescope, and it has been shown conclusively that it is a matter of indifference whether a star is bisected by moving the wires towards the micrometer head or in the opposite direction.

It had been found that the nadir point was sensibly affected by the unequal expansion of the telescope tube caused by heat from the observer's body; it has been judged necessary, therefore, to protect the tube by a quilted calico covering from sudden changes of temperature due to this cause.

It is thought probable that the discrepancies between the results of direct and reflected observations, known as the "Discordances of Zenith Points," are mainly occasioned by these unequal expansions of the telescope tube, but that they are also in part due to inequality in the refractions suffered by the direct and reflected rays in their respective passages from the external air to the observer's eye.

In order to throw light on the latter point several good standard thermometers have been procured and experiments with them are in progress for comparing from time to time the temperatures in different parts of the transit room with that of the external air.

Dunsink.

The South Equatoreal has been employed in observations of annual parallax. A series of differences of declination between 61 *Cygni* and a neighbouring star was completed and shows a parallax of 0″·4654. A set of measures of the distance and position from Groombridge 1618 to an adjacent star will be completed in March, and systematic observations of two other stars have been commenced. Measurements of a large number of other stars have

been made, with the view of selecting those which will be suitable for regular parallax observations.

Mr. Burton having resigned on account of ill-health, Mr. Dreyer took charge of the Meridian Circle at the end of last August.

The observations of red stars, which, for various reasons, had not made much progress for some time, form this winter the only object of observation, and will, it is hoped, be finished in the coming summer. When the resulting positions of red stars have been brought out in the course of next winter in Part IV. of the *Dunsink Observations*, it is intended to devote the Meridian Circle to a longer series of observations of stars with large proper motion.

Royal Observatory, Edinburgh.

At the Royal Observatory, Edinburgh, the work has consisted nearly as usual in time observations, daily time signals by ball and gun, and control of public clocks; also in the extensive meteorological computations required by the Registrar-General for Scotland to illustrate the climates of fifty-five observing stations spread over the whole of North Britain.

The Assistant Astronomers, Mr. Alexander Wallace, M.A., and Mr. Thomas Heath, B.A., have further done good work in perfecting the MS. of additional portions of the Star Catalogue to what was contained in vol. xiv. of the *Edinburgh Astronomical Observations*. And the Astronomer has succeeded in observing carefully the whole solar spectrum, by eye and glass transmission, to an extent of 2,200 micrometer measured lines, or about 1,000 more than what are contained in Angstrom's excellent *Normal Solar Spectrum Map*. Most of these additional lines are far too faint to be of much importance; but an occasional strong case of anomaly has been found which must signify either an accidental error in Angstrom or a variation in the quality of solar radiation with time. In preparation for the possibility of something of the latter kind eventuating, this Edinburgh Solar Spectrum has been entitled as "for the *epoch* 1878.'

The Edinburgh Royal Observatory hopes to have the power of printing its observations restored to it before long, as well as that something may at last be done for strengthening the establishment in the directions pointed out by both the Commission of Enquiry two years ago, and the many persevering annual reports of the Edinburgh, Government appointed, Board of Visitors.

Kew Observatory.

The astronomical work of this Observatory has been confined during the past year to the continued measurements of the Sun-pictures taken during the years 1862-71, which has been carried on at Mr. De la Rue's expense and under his direction.

On account of the large number of spots which appeared on the Sun's disk during the years 1870 and 1871, it has not been found possible to complete the whole series of pictures, but measurements have been made up to the end of February 1872, and it is contemplated that another month will suffice for finishing this branch of the work, as the Kew series ends on April 9, 1872.

The reduction of the measurements to heliocentric elements has been continued by Mr. Marth for Mr. De la Rue.

The eye observations of the Sun after the method of Heinrich Schwabe have been made daily, when possible, in order for the present to maintain the continuity of the Kew record of Sun-spots.

The question of observing solar radiation having been referred by the Meteorological Council to the Kew Committee, a sub-committee has been appointed to take the whole subject into consideration.

The Campbell Sundial continues in action, and the improved form of the instrument, giving a separate record for every day of the duration of sunshine, has been regularly worked throughout the year and its curves tabulated.

The magnetical and meteorological work, to which the attention of the Observatory is chiefly directed, has been prosecuted continuously, and the Verification Department has been fully occupied the whole year.

Liverpool Observatory, Bidston, Birkenhead.

The general work at this Observatory during the past twelve months has differed but little from that of preceding years.

A large amount of information is now being collected with regard to the performance of chronometers at sea.

Probably but few persons are aware of the degree of accuracy which may be attained in the determination of the longitude of a ship at sea by the application of corrections due to change of temperature to the rates of chronometers. For the last sixty chronometers returned to the Observatory, the average length of voyage is 110 days, and for the best thirty of them, or half of these, the mean error—that is, the difference between the error of

the instrument on Greenwich mean time as found by calculation, by using a variable rate dependent on the temperatures to which the instrument was exposed during the voyage, and the absolute error on Greenwich mean time as found by comparing the instrument with the normal clock at this Observatory—is 9·3 seconds, or under two and a half geographical miles on the Equator after a voyage of nearly four months.

Temple Observatory, Rugby.

The principal work of the Observatory during the year 1878 has been the measurement of position and distance of 65 double stars, a number somewhat less than that of previous years, owing in a great measure to the fact that the attendance of members of the school and the time given to them has been very considerably increased since the Observatory has been built on the present site.

The measurements are chiefly of stars contained in a list made by Mr. Wilson of well ascertained binaries.

Mr. S. has given further attention to the measurements of the motions of recession or approach of stars with the large spectroscope on the reflector, and has taken 23 sets of measures, but the available evenings have been few.

The educational use of the Observatory has during the past year largely increased, 352 names appearing in the note book. We are sorry to have to record the fact of Mr. Wilson's withdrawal from the direction of this Observatory, in consequence of his appointment to the head mastership of Clifton College.

The Temple Observatory will now be under the direction of Mr. Seabroke.

Stonyhurst Observatory.

The astronomical work in this Observatory was considerably interfered with by the absence of the object-glass of the large Equatoreal during the first six months. One of the surfaces of this glass has been reground by Mr. J. Simms, and the definition has thus been considerably improved.

The eclipses of *Jupiter's* satellites were observed with a 9-inch Cassegrain during the polishing of the lens of the Equatoreal; and this Cassegrain and a 4-inch achromatic by Jones were in readiness for the transit of *Mercury* on May 6, had the state of the sky been favourable.

The improvement of the Refractor has caused the double-star work to be undertaken more perseveringly than formerly, and a large spectroscope is now in course of construction for the Observatory, which will be employed principally in daily work on the Sun.

The Director of the Manila Observatory has spent some time at Stonyhurst in the course of the year, and a first-class theodolite and standard astronomical clock are shortly to be sent to his distant station.

A chronometer and dip circle have also been lately tested at this Observatory, previously to being taken out to the South of Central Africa by some missionaries who sailed in January from Southampton.

Mr. Barclay's Observatory.

The principal feature of the past year's work has been the publishing of the fourth volume of the *Leyton Astronomical Observations*. As stated in a previous Report, it is considered best to publish frequently, even if the number of observations be comparatively small, as an accumulation of unreduced observations, which is apt to become overwhelming, is prevented, and observations which may perhaps be useful to others are immediately available.

The instruments remain as before described. The whole of the Equatoreal has this year been dismounted for the purpose of cleaning the various bearings. It has hitherto been found impossible to obtain an oil that does not thicken and become as tenacious as glue.

Colonel Cooper's Observatory, Markree.

During the past year double stars and planets have been systematically observed at this Observatory with a number of different micrometers. With the Munich spider-lines micrometer both angles and distances were measured directly, and the same apparatus was used for oblique transits. With the prismatic double-image micrometer I could only measure distances. With the square-bar micrometer I observed differences of R.A. and Decl.

At present I observe systematically all double stars of between 65° and 85° Decl. north (with the exception of such objects as are positively known to be motionless from previous

investigations). If the observation agrees with the earlier results, I do not examine the object again; but if I find a difference, I continue the measures in order to form a reliable epoch.

The severe frost which occurred at the end of last year interfered a good deal with the working of the large telescope. A couple of nights the tube was so hard to move in R.A. that it took two strong men to alter it, and subsequently the observations had to be given up, the telescope being all covered over with snow and frozen, as was also the yard where it is placed.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

No important change in the work of this Observatory has taken place since the date of the last Report. Measures of double stars have been made, phenomena of *Jupiter's* satellites observed, and a new micrometer, by Simms, carefully tested; but the principal work of the Observatory has been the compilation of notes on double stars and the collection of measures for the purpose of forming a catalogue of binaries. The new driving clock, by Mr. Grubb, was fixed in July, and has been found both powerful and effective.

Mr. Huggins' Observatory.

During the past year the work of obtaining photographs of the spectra of stars has been pursued whenever the weather has been sufficiently favourable. Considerable progress has been made; but for this work only the finest nights are available. On the occasion of the transit of *Mercury* arrangements were made to obtain a photograph of the spectrum of *Mercury* superposed on the solar spectrum, chiefly to observe if any modifications of the solar spectrum due to an atmosphere were to be found near the limbs of the planet. Unfortunately, the weather was not sufficiently favourable at the time of the transit.

Observatory, Birr Castle.

During the earlier part of the year 1878 the observations were carried on as usual at the Observatory of Birr Castle, but work was not resumed at the telescopes after the short nights of the summer solstice. My assistant, Mr. J. Dreyer, left for

Dunsink towards the end of August, the preparation of Part II. of *Observations of Nebulæ* having been completed for sending into the Royal Dublin Society, and the observations for Part III., which completes the work, having been carried on as long as was deemed necessary before closing the series.

As I was leaving home in July last, with little hope of returning to reside there for a year or more, I was unable to take steps for engaging in any new line of work, and except for taking the 9 A.M. and 9 P.M. meteorological readings, the Observatory remains closed for the present.

The 12·45 P.M. G.M.T. "Synchronous" meteorological observations have been discontinued.

Colonel Tomline's Observatory, Orwell Park.

The past year having been on the whole unfavourable to equatoreal observation, the opportunity has been taken to complete the reduction of arrears of all kinds. The cometary observations of 1877 have been fully reduced and the results have been sent to the Editor of the *Astronomische Nachrichten* for publication in that journal.

The longitude of the Observatory has been determined by the method of the Moon and culminators, and the result, $4^m\ 57^s{\cdot}75$ E., exceeds by nearly two seconds that inferred from the Ordnance Survey. This result is scarcely definitive, as other observations exist for which the corresponding ones at Greenwich are not yet published; but, depending as it does on an equal number of observations (11) of either limb of the Moon, it is not anticipated that any sensible alteration will require to be made.

A great number of transit observations of stars have likewise been reduced, which are expected to yield some interesting results bearing on proper motion.

Tempel's comet has been looked for on several occasions, but, owing to persistent cloud and haziness near the horizon, has not been seen. The like ill success in the case of Swift's comet is explained by the unfortunate misinterpretation of the telegram announcing its discovery.

The transit of *Mercury* on May 6 was very fairly observed, and afforded gratifying proof of the excellence of definition of the object glass.

It was found necessary in September to dismount the telescope in consequence of some particles of rust having found their way into the bearing of the declination axis, almost entirely preventing the movement. The rust was removed by Mr. Simms, and since that time the working of the instrument has been quite satisfactory.

Royal Observatory, Cape of Good Hope.

The reobservation of the stars in Lacaille's zones is finished. All the reductions are completed, and 9,000 stars are accurately reduced to epoch, and have their precessions and secular variations computed and examined. The rest of the observations are very approximately reduced to epoch, and the computation of the precessions and secular variations is being pressed forward as rapidly as possible. We are now only observing stars to fill up a few *lacunæ* which have been detected on projecting our places on a large scale chart for that purpose.

The Catalogue will probably be completely finished before Mr. Stone leaves the Cape in the middle of June, and it will contain about 13,000 stars. Mr. Stone intends to bring the work home to be printed, as the printing at the Cape would take two years.

The volume for 1876 has long been finished and is now nearly printed. The printing has been delayed to pass through the press the Catalogue for 1860, which will be bound up with the 1876 volume as an appendix.

Melbourne Observatory.

During the past year the meridian observation at this Observatory has been somewhat relaxed in order to give more time for the reduction of the zone observations between the parallels 150° and 160° N.P.D., and it has therefore been chiefly confined to the routine observations of fundamental clock and circumpolar stars. In November, however, a series of observations was made for the determination of the R.A. of certain stars selected by Mr. Gill to enable him to investigate certain systematic errors in the Right Ascensions of the *Mars* comparison stars as determined at various Observatories.

The Great Telescope continues in good working order, and has been devoted steadily to the revision of Sir John Herschel's figured nebulæ. Nos. 4223 and 1561 of the General Catalogue, widely separated from each other, and described by Herschel as prominent objects, cannot now be found. The nebula around *η Argûs* was carefully compared with the drawings of March 1876; the only change which has been clearly established since that date is a break or separation in one of the branches on the preceding side. Among other work the Trifid Nebula has occupied some attention, and the drawing, which, however, is not yet quite complete in all its details, agrees fairly with Mr. Lassell's drawing of 1862, the three principal stars near the centre being unmistakably involved in the nebula.

The drawings of all the nebulæ made at the Great Telescope, although lithographed, have not yet been published, owing to unforeseen delays in the Government printing departments.

The 8-inch Refractor has been employed partly in planetary observation, but principally on southern double stars, in continuation of a revision of Sir John Herschel's list.

Sun-pictures have been obtained every day with the photo-heliograph, and the absence of sun-spots during the year has been very remarkable.

The usual meteorological and magnetical work has been carried on uninterruptedly.

The transit of *Mercury*, which took place on May 7, had passed through its earlier phases before the Sun rose above the Melbourne horizon; the latter phases, however, were all observed and the results have appeared in the *Astronomical Notices*.

The only astronomical publication issued during the year was a pamphlet containing the observations of *Mars* and comparison stars at the opposition of 1877.

The meteorological publications issued are the *Monthly Records of Meteorology and Terrestrial Magnetism* and the *Meteorological Results for the year* 1876.

The establishment and instrumental appliances are in an excellent and effective condition; it is proposed, however, to replace the present Transit Circle, which has a telescope of 5 inches aperture, with one similar to that at Cambridge (England), which has an objective of 8 inches diameter, and the Colonial Government has already testified its readiness to furnish the requisite funds.

Notes on some points connected with the Progress of Astronomy during the past year.

Professor Newcomb's Researches on the Moon's Motion.

For several years Professor Simon Newcomb has been engaged on some important researches on the motion of the Moon. As originally planned by him, the work was divided into two portions; I. the mathematical theory of the inequalities of long period in the Moon's mean motion; and II. the reduction and discussion of the observations of the Moon made prior to 1750. With the aid of a grant from Congress these two portions were carried on simultaneously, with the intention of completing them in the above order. But when the mathematical investigation was supposed to be brought nearly to a close, it was found that certain terms which were at first supposed to be of no importance would have to be investigated, and that this investigation might prove the most tedious part of the whole work unless some method of shortening it could be devised. Professor Newcomb has not yet been able to decide which is the best method of treating the subject; the investigation is still incomplete; so the portion intended as Part II. has been issued as Part I. of these researches.

In the last Report of the Council an account is given of the principal results which have been deduced from his researches by Professor Newcomb. The full details of these researches are now published, and form Appendix II. to the *Washington Observations* for 1875. The volume contains a full account of the reduction and preliminary discussion of the observations of the Moon made before 1750. Professor Newcomb critically examines all the ancient eclipses of the Sun, but rejects them as being too uncertain to afford trustworthy data. From the eclipses of the Moon quoted by Ptolemy, Professor Newcomb deduces the correction to the places of the Moon at the four early epochs B.C. 687, 381, and 189, and A.D. 134. By reducing the observations of the eclipses observed by the Arabian astronomers during the ninth and tenth centuries, Professor Newcomb deduces the errors of Hansen's tables for the epochs A.D. 850, 927, and 986. A few of these observations are found to be discordant with the rest and two to be irreconcilable with theory, possibly, as suggested by Mr. Knobel, through errors in copying one letter for another closely resembling it.

The most important portion of the volume is the complete reduction of the observations made between 1625 and 1750.

These consist mainly of four eclipses and twenty occultations of stars observed by Bullialdus and Gassendi between 1620 and 1642; six eclipses and sixty occultations observed by Hevelius between 1639 and 1684; three eclipses and twenty-four occultations observed by Flamsteed between 1676 and 1716; six eclipses and ninety-seven occultations observed by La Hire, the Cassinis, Maraldi, and principally at the Paris Observatory between 1670 and 1740; and seventy-seven occultations observed by Delisle between 1714 and 1748, partly at the Luxembourg at Paris, and partly at St. Petersburg. Some of these observations have had to be rejected, principally from some uncertainty attaching to them, as, for instance, in the case of most of the occultations of stars by the bright limb of the Moon. Nearly two-thirds of them, however, are good observations, which can be used to determine the errors of the lunar tables for different periods between 1650 and 1725. They are sufficiently numerous to enable the mean errors of Hansen's tables to be determined with a probable error of only $1''{\cdot}5$ for any period between 1670 and 1740. Between 1625 and 1670 the probable error of the observed place is much greater, amounting to about $5''$.

In the last portion of the volume Professor Newcomb proceeds to discuss these observations and correct the elements of Hansen's tables. The results of his investigations have been already described in the last Report of the Council, and need not be again repeated.

There can be no doubt that these researches of Professor Newcomb, embodied in this volume of the *Washington Observations*, form a most important contribution to our knowledge of the motion of the Moon, and, by furnishing the mathematician with most valuable data, tend very materially to advance the theory of the motion of the Moon. It will make astronomers look forward with impatience to the publication of the second part of the research—the mathematical treatment of the theory of the terms of long period.

In relation to Professor Newcomb's volume Mr. Neison has remarked (*Monthly Notices*, vol. xxxi., p. 73) that if one of the eclipses be omitted, the value of the correction to the secular acceleration rises from $-3''{\cdot}81$ to $-4''{\cdot}80$; and that if two other eclipses which Professor Newcomb regards as doubtful be omitted, Hansen's value of the secular acceleration can be reduced to $7''{\cdot}20$, or only a single second greater than the theoretical value, $6''{\cdot}18$.

In a previous paper, "On Hansen's Terms of Long Period in the Lunar Theory" (*Monthly Notices*, vol. xxxviii., p. 268), Mr. Neison has given the results of a careful investigation in regard to the two terms of long period in the motion of the Moon due to the perturbations of *Venus*, which were discovered by Hansen. Purely empirical values were assigned by Hansen to the coefficients of these important terms. Delaunay found that the theoretical value of one of the coefficients was so small

that it might be regarded as insensible. This result was confirmed by Professor Newcomb, and Mr. Neison has sufficiently verified Delaunay's investigations to satisfy himself that they are free from serious error. Nevertheless, Mr. Neison arrives at the important and remarkable conclusion that it is possible that, after all, Hansen's result may be right, and he explains in the paper how this may be produced.

Mr. Hill's Researches on the Lunar Theory.

During the course of the past year mathematical astronomy has received an important contribution from the publication in the *American Journal of Mathematics* of Mr. G. W. Hill's "Researches on the Lunar Theory," a paper communicated to the American Academy of Sciences in April 1877. In these investigations Mr. G. W. Hill has regarded the problem from rather a different point to that usually adopted, and his aim is expressed in the opening paragraph of his paper in the following words:—

"When we consider how we may best contribute to the advancement of this much treated subject, we cannot fail to notice that the great majority of writers on it have had before them, as their ultimate aim, the construction of tables; that is, they have viewed the problem from the standpoint of practical astronomy rather than from that of mathematics. It is on this account that we find such a restricted choice of variables to express the position of the Moon, and of parameters, in terms of which to express the coefficients of the periodic terms. Again, their object compelling them to go over the entire field, they have neglected to notice many minor points of great interest to the mathematician, simply because the knowledge of them was unnecessary for the formation of tables. But the developments having now been carried extremely far without completely satisfying all desires, one is led to ask whether such modifications cannot be made in the processes of integration, and such coordinates and parameters adopted, that a much nearer approach may be had to the law of the series, and, at the same time, their convergence augmented."

Mr. Hill adopts rectangular coordinates instead of the usual polar coordinates, with the idea of simplifying the expression for the disturbing function and the perturbations. It is his opinion that the perturbations of the rectangular coordinates will be simpler in form than the perturbations of the ordinary system of polar coordinates; and in support of this view Mr. Hill adduces the case of elliptic motion, where the rectangular coordinates can be expressed by a series of circular functions of the time with coefficients of comparatively simple form

whose general term is known; whereas, in the case of the ordinary polar coordinates the coefficients of the series of circular functions are more complex and cannot be expressed by a general term of simple form.

Mr. Hill proceeds to convert the ordinary differential equations into the particular form made use of by him, the system of rectangular coordinates being supposed to rotate with the same velocity as the mean motion of the Earth, so that one of the axes always passes through the mean place of the Sun. He then proceeds to introduce as auxiliaries two new imaginary variables instead of two of the rectangular coordinates, and to transform the differential equations and disturbing function into terms of these new quantities. These new variables perhaps might be termed the imaginary square roots of the radius vector, and it is by the aid of these auxiliaries that Mr. Hill deduces the lunar perturbations. In the subsequent stages of his researches Mr. Hill supposes the eccentricities of the terrestrial orbit and the inclination of the lunar orbit, together with the solar parallax, to be so very small that they can be neglected. Under these conditions he is able to deduce two symmetrical differential equations of the second order in terms of the two imaginary auxiliary variables, and then, by suitably combining them, Mr. Hill derives two new differential equations which have the advantage of being symmetrical homogeneous equations of two dimensions, and well suited for the purpose of deducing the relations connecting together the different coefficients of the periodical perturbations.

Mr. Hill then proceeds to still further restrict the scope of his investigations by supposing the eccentricity of the orbit of the Moon to be so small that it can be neglected, and takes up the special consideration of the class of lunar perturbations which depend solely on the ratio between the mean motions of the Earth and Moon. He assumes that the variables are functions of these terms only; and he supposes that the values of the two rectangular coordinates of the Moon are expressed by a series of cosines and sines of the difference between the mean motions of the Earth and Moon, each periodical term being supposed to have an indeterminate coefficient. Mr. Hill then transforms his auxiliary imaginary variables into a series of powers of an imaginary exponential function of the time, with the same indeterminate coefficients as the series of cosines and sines expressing the value of the rectangular coordinates. It only remains, therefore, to deduce the value of these indeterminate coefficients by means of the equations involving the auxiliary variables, and, by substituting them in the series for the rectangular coordinates, their values will be obtained at once, without any further transformations or operations.

Substituting in the differential equations these expressions for the auxiliary variables, Mr. Hill is able to deduce equations connecting together the different indeterminate coefficients,

and so find an expression for the value of any single coefficient in terms of the other coefficients of the series. This constitutes Mr. Hill's solution of the problem. It gives the value of the perturbation in the form of a series of terms each of which has a coefficient consisting of a doubly infinite series which is a function of the other coefficients of the series. The method gives, however, only those terms which are independent of the eccentricity and inclination of the orbit of the Moon and the eccentricity of the orbit of the Earth and the solar parallax.

By means of these investigations Mr. Hill is able to deduce with accuracy the portion of the perturbations of the Moon which depend solely on the ratio of the mean motions of the Earth and Moon. They are calculated to the 14th decimal place by an arithmetical process, and to the order m^9 by algebraical development.

The concluding part of this portion of Mr. Hill's researches on the lunar theory is devoted to the special consideration of these results as applied to particular cases of the problem of a satellite moving in a circular mean orbit and disturbed by the action of a very distant body in the plane of the orbit.

The preceding account of these researches of Mr. Hill's will show that they form an important contribution to astronomy, and the highly original and powerful method by which Mr. Hill has attacked the problem will be generally admired. And if opinions may differ on some of the conclusions arrived at by Mr. Hill in the course of his researches, there cannot be any question as to the value of this important addition to our knowledge of the Lunar Theory.

Mr. Darwin's Investigation of the Influence of Geological Changes on the Earth's Axis of Rotation.

In a paper "On the influence of Geological Changes on the Earth's Axis of Rotation," * Mr. G. H. Darwin has considered the rotation of a spheroidal body which, from internal forces, is slowly and continuously changing its shape to a small extent. He arrives at the conclusion that, with changes such as those which geologists observe, the instantaneous axis of rotation would always remain sensibly coincident with the principal axis of figure, and that the change in the obliquity of the ecliptic could not exceed a small fraction of a second of arc. The principal axis of figure would, however, wander from its primitive geographical position in the Earth, and would carry along with it the instantaneous axis of rotation, the extremity of which would describe, at the Earth's surface, a cycloidal

* *Phil. Trans.*, vol. 167, part I., p. 271.

curve of very small linear dimensions, the two axes being coincident every 306th day. If the Earth be considered as plastic, it appears that its rotation would have the effect of modifying the path described in the body by the principal axis, under the influence of the internal forces. From this the author concludes that it is probable that, during the consolidation of the Earth's mass, the geographical position of the poles may have varied to a considerable extent.

The author then considers what amount of geographical change in the position of the poles in the Earth might arise from geological changes, and investigates the forms of elevation and depression which would produce a maximum effect. He concludes that, if the Earth were absolutely rigid, the pole could never have wandered more than from 1° to 3° from its primitive position; but that, if the Earth's mass be sufficiently plastic to admit of rough adjustments to an approximate form of equilibrium from time to time, then the wandering of the poles might be cumulative in successive geological periods. He regards it, however, as excessively improbable that the poles could thus have wandered more than 10° or 15° during geological history. The geographical changes in climate, observed in the geologically recent glacial epoch, seem too great to admit of explanation from this cause. The problem of the rotation of the Earth as modified by geological changes was considered from a more strictly astronomical point of view by M. Gyldèn in 1871; and Professors Haughton and Twisden have recently communicated papers to the Royal Geological Society on the same subject, which bear more on the geological aspects of the case.

Total Solar Eclipse of 1878, *July* 29.

Although no grant of money was made by the Government or from the funds of the learned societies for the observation of this eclipse, several English observers, at their own expense, transported themselves and their instruments, which in some instances were very bulky, to the Western States of America, for the purpose of placing themselves upon the line of totality. All the English observers were rewarded by fine weather.

The eclipse, which was visible along a track which passed across the States of Colorado and Texas, was also well observed by a large number of American astronomers, some of whom obtained excellent photographs of the corona, showing structure which differs materially from the structure visible in the photographs of the corona taken in 1871 near to a period of sun spot maximum. One of the English observers also obtained two photographs of the corona, which have since been presented to

the Society, and can be seen on applying to the Assistant-Secretary.

The stations of the English observers were as follows: Mr. Lockyer at Rawlins, Wyoming Territory; Mr. Loder, Mr. Penrose, and Mr. Ranyard, all within a few miles of Denver, Colorado; Dr. Schuster, Dr. Thorpe, and Mr. Hoskins at Las Animas, South Colorado.

Reduction of the Observations of the Transit of Venus of 1874.

The work in connection with the English Government Expedition has not proceeded as rapidly as in former years, Her Majesty's Treasury having, since the 31st of last March, refused to grant further pecuniary assistance. The work is too heavy to throw upon the Staff of the Royal Observatory, and must have collapsed had it not been continued at the expense of the Astronomer Royal and Captain Tupman. For the last eight months the latter has been working at the preparation of the calculations for the press without any assistance.

Considerable progress has, however, been made. When it was found that Mr. Burton's measures of the photographs presented such grave discordances, the Astronomer Royal requested Captain Tupman to remeasure the photographs; but no greater success was obtained.

A discussion of the Solar Parallax from every available observation of the recent transit was then undertaken, and the results, as well as those from the photographs, were presented to the Society in June.

Since then the details of the operations at the various Government stations, the bulk of which relate to the terrestrial longitudes, have been preparing for press. This is not very straightforward work, for small errors of calculation or transcribing are continually being detected and have to be corrected. It is in this that an assistant is most needed. The press copies may be said to be ready for the stations at Mokattam, Honolulu, Kailua, and Waimea. For Rodriguez the transits of stars are ready. It is not in contemplation to include the details of photography in the work.

It is believed that the whole will be printed in the form, and will constitute a portion, of the *Memoirs* of the Society.

Abroad, we have to notice that the French Commission has published the details of the Expedition to the Island of St. Paul under Captain (now Admiral) Monchez. About one-fourth of the work is devoted to the astronomical observations, the remainder to photography, pendulum experiments to determine the intensity of gravitation, magnetic observations, hydrography, and other valuable researches.

The Russian Commission has published the measures and the discussion, by Dr. Hasselberg, of 22 photographs taken at Hafen Possiet with an instrument, by Dallmeyer, similar to those used by the British parties. The position angles, as well as the distances of the centre of *Venus* from the centre of the Sun, have been most carefully determined. In the former a mean error of 10′ is found; for the latter a mean error of 1″—that is, of about one-twelfth part of the relative parallactic displacement of the centres. Compared together by reduction to one standard—that is, by eliminating the motion of the planet, the individual photographs vary as much as 4″ in the deduced distance of centres, much the same result as was obtained from the British photographs. In the Russian photographs the instrumental distortion was eliminated by employing a reticule of numerous lines, the positions of which, as depicted on the collodion, were determined by observation.

Elements of Vulcan.

The question of supposed transits of an intra-Mercurial planet has been again taken up by M. Oppolzer (*Astronomische Nachrichten*, No. 2239), who has collected the following eight observations, which may, he considers, refer to the transits of the same body:—

		d	Sun's Longitude. °	
1800	March	29·0	9 14	Fritsch
1802	Oct.	10·0	197 6	Fritsch
1819	Oct.	9·0	195 45	Stark
1839	Oct.	2·0	188 44	Decuppis
1849	March	12·18	352 2	Sidebotham
1857	Sept.	12·00	169 33	Ohrt
1859	March	26·22	5 23	Lescarbault
1862	March	19·87	359 20	Lummis

Five of these had been used by Le Verrier in his discussion published in the *Comptes Rendus*, tome lxxxiii., 1876, and to them M. Oppolzer has added the first observation by Fritsch and the two by Stark and Ohrt, which Le Verrier had rejected on the ground that no mention was made of any motion of the spot. The whole of the eight observations are well represented by the following elements:—

1850, Jan. 1·0, Paris M.T., Mean Equinox 1850·0.

M	356° 0′	i	7° 0′
π	27 45	μ	22°·789529
ϕ	14 13	log a	9·0906
Ω	178 0		

This planet is not identical with either of the objects seen by Watson in the late eclipse; it was at that time about 7° east of the Sun and in north latitude.

On further consideration, however, M. Oppolzer finds that there are various circumstances which tend to shake our confidence in these elements:—

(1) With such a small inclination and period of revolution, a transit should take place every year in March as well as in October, and it is difficult to account for the fact that more frequent observations of such phenomena have not been made.

(2) The representation of the earlier observations requires a large retrograde movement of the node.

(3) The duration of the transits corresponds well with the observations of Lescarbault, Loomis, and Decuppis, but is too small for Fritsch's observation in 1800, which requires a duration of 10 to 11 hours.

(4) For Sidebotham's observation in 1849 the time of conjunction falls in the early hours of the night.

Further, considering that by making the periodic time sufficiently small, a satisfactory solution may always be found, we may be inclined to think that the satisfactory representation of eight observations is merely an accidental coincidence. The question can be decided by observations on March 18 next, when, according to M. Oppolzer's elements, a transit will occur as follows:—

		Berlin M.T. h m	Pos. Angle. °
Ingress	1879 March 18	18 8	74
Egress		23 15	254

Discovery of Minor Planets.

The following minor planets have been discovered during the past year. The total number is now 191.

No.	Name of Planet.	Date of Discovery. 1878.	Place of Discovery.	Name of Discoverer.
(184)	Deiopeia	February 28	Pola	Palisa
(185)	Eunike	March 1	Clinton, U.S.	C. H. F. Peters
(186)	Celuta	April 6	Paris	Prosper Henry
(187)		April 11	Marseilles	Coggia
(188)	Menippe	June 18	Clinton, U.S.	C. H. F. Peters
(189)	Phthia	September 9	Clinton, U.S.	C. H. F. Peters
(190)	Ismene	September 22	Clinton, U.S.	C. H. F. Peters
(191)	Kolga	September 30	Clinton, U.S.	C. H. F. Peters

Planets (173), (177), (180), and (181), discovered in the preceding year, have respectively received the names of *Ino*, *Irma*, *Garumna*, and *Eucharis*.

Discovery of Comets.

Four comets have been observed since the date of the last Report, three of which are comets of short period.

1. A faint telescopic comet, discovered on July 7, 1878, by Mr. Lewis Swift, at Rochester, U.S. This comet was not observed in Europe, though carefully searched for; but Dr. Peters, of Clinton, U.S., succeeded in making four observations, from which Dr. Holetschek has calculated the elements of its orbit.

2. Tempel's second periodical comet, discovered in 1873, was first seen by M. Tempel on July 19, 1878, at the Arcetri Observatory, Florence. This comet has also been observed at several other Observatories.

3. Encke's periodical comet, whose return to perihelion was expected last year, was independently detected on August 3, 1878, by Mr. Tebbutt, at Windsor, New South Wales, and by Dr. Gould, at the National Argentine Observatory, Cordoba, by the aid of Von Asten's ephemeris in No. 2197 of the *Astronomische Nachrichten*. Dr. Gould has made a valuable series of observations, assisted by Mr. Thorne, extending from August 7 to September 6. He remarks that "the comet appeared nearly circular throughout the whole period of observation, and until August 26 a slight increase of brightness towards the centre was appreciable. Its light on August 10 was comparable with that of a star of the eighth magnitude; but, although the comet was moving southward and eastward, its light decreased so rapidly, that during the last ten days it was difficult to keep it in view while near the illuminated threads of the telescope. On August 17 the apparent diameter of the comet was very nearly one minute of arc."

4. Brorsen's periodical comet was found by M. Tempel, at Florence, on January 14, 1879, very near to the horizon. According to the elements calculated by Professor Schulze, the date of its return to perihelion is March 30; it has therefore been seen much earlier than was expected. In April and May this comet will be more favourably situated for observation in northern latitudes than at the last appearance in 1868.

Schmidt's Charte der Gebirge des Mondes.

This grand work, the labour of a lifetime, was published at Berlin in the early part of last summer. It forms a complete map of the lunar surface on a scale of 75 inches to the diameter

of the Moon, which is twice as great as the scale of either Lohrmann's larger map or of the well known *Mappa Selenographica* of Beer and Mädler. Schmidt's new map is divided into twenty-five sections on exactly the same plan as Lohrmann's Mondcharte, showing the same region, only on twice the scale—four times the area. The map is based exclusively on the trigonometrical survey of Lohrmann's, made in 1824 and published complete for the first time in 1878. This survey is far less extensive than that of Beer and Mädler, so that it forms a less accurate basis for a map, and on this account Schmidt's map shows systematic differences when compared with Beer and Mädler's *Mappa Selenographica*. The whole of the detail shown on Schmidt's map is derived from his own numerous drawings of the different lunar formations; so that, with the single exception of the relative position of the principal lunar central peaks, the new chart of Schmidt's is an absolutely independent delineation of the surface of the Moon. The published maps are exact reproductions by photolithography of the original pen and ink drawings of Herr Schmidt.

The portfolio of sections of this great map is accompanied by a short explanation of 20 pages, giving the names of the different formations, for the chart itself contains only letters and numbers. There is also published a quarto volume giving a fuller explanation of the chart, a comparison between the symbols of Lohrmann and Mädler, and a full account of the measures of the heights of the principal lunar peaks, made by Schroter, Mädler, and Schmidt. Although there are a few notes to each section, there is no detailed descriptive account of the principal formations on the lunar surface, though this feature is fully as important as the mapping of the surface, and forms an essential part of the great work of Beer and Mädler.

The history of this great chart of the Moon is well known to astronomers, who have for several years been anxiously awaiting its publication. Herr Julius Schmidt commenced accumulating material for his new chart whilst at Hamburg in 1843; and between 1843 and 1874 made more than three thousand drawings of different portions of the Moon. From these drawings the present map was constructed, a work fully occupying his time between April 1867 and July 1874. After some uncertainty as to the best method of publishing, Herr Schmidt accepted the offer of the German Government, and it is at their cost that the work has been at last published. It forms a most elaborate map of the detail of the lunar surface and is an important contribution to selenography.

Lohrmann's "Mondcharte."

After an interval of more than half a century, the remaining twenty-one sections of Lohrmann's large map of the Moon have at

length been published. Lohrmann was a land surveyor of Dresden, in the service of the Saxon Government, and an enthusiastic amateur astronomer. Encouraged by Gauss and Encke, he undertook the construction of a complete map of the Moon, employing a fine 5-inch Frauenhofer Equatoreal. The map was founded on a micrometrical triangulation of the principal points on the lunar surface, the measures being reduced by means of formulæ supplied to him by Encke. Lohrmann divided his map into twenty-five square sections on the scale of $37\frac{1}{2}$ inches to the diameter of the Moon, and he intended each section to be accompanied by a full description of the principal features of the portion of the lunar surface included within it. After four years' labour, the first four sections, with a descriptive letterpress, were published in 1824, and were warmly welcomed by astronomers as an important contribution to science. The second instalment of the work was anxiously expected, but it did not come. Up to 1827 Lohrmann had energetically continued his labours, but failing eyesight then compelled him to suspend his work. He never recovered sufficiently to enable him to resume his observations, and he died in 1840, leaving his work incomplete. It was generally supposed that, though he had issued, in 1837, a small lunar chart (15 inches in diameter), he had never completed the remaining sections of his large map. It now seems that this was not the case, and that, though Lohrmann had not obtained all the material that he desired, yet he had finished his sections on the basis of the observations made between 1821 and 1827. After many long delays, the remaining sections of Lohrmann's map have been engraved under the superintendence of Herr Julius Schmidt, the well known selenographer, and they were published at the beginning of last year. It would appear that Lohrmann left no written description to accompany his maps. The sections having been reproduced without alteration from Lohrmann's original pen and ink drawings, they represent a careful delineation of the lunar surface as it appeared half a century ago, and they form an important addition to this department of astronomy.

Publications of the Astronomical Observatory of Harvard College.

Since the last Annual Report of the Council, the Observatory of Harvard College has published some most important contributions to Sidereal Astronomy.

Vol. iv., part 2, of the *Annals*, published in 1878, contains the observations in Right Ascension of 505 stars determined with the East Transit Circle in the years 1862–65, under the direction of Professor G. P. Bond, and Professor T. H. Safford, who has now reduced the observations.

One chief difficulty in the instrument with which these

observations were made was the absence of collimators, and the collimation had to be determined by reversals on a distant mark. Professor Safford remarks, that "as the work progressed, and various discrepancies between the observations and some of the principal ephemerides became manifest, it was almost invariably found that the observations were the more accurate of the two."

The General Catalogue gives the mean Right Ascension to $0^{s}\cdot001$ of 506 stars for the epoch of 1865·0, with their precessions and secular variations computed from Bessel's elements, using Argelander's precepts and Tables in vol. vii. *Bonner Beobachtungen*. In the large majority of stars proper motions are given, derived from Argelander, Newcomb, Mädler, Von Asten, Wagner, Wolfers, Rogers, and Safford. Approximate declinations are appended. The Catalogue includes all the stars of the *Nautical Almanac* visible at the latitude of Cambridge, omitting Maskelyne's 36 stars; also 22 polar stars whose places were investigated in vol. iv., part 1, of these *Annals*,* and some other bright stars taken from the *Connaissance des Temps*, the *American Ephemeris*, and Argelander's *Gemeinschaftliche Sterne* and *Uranometria Nova*.

One especial value of this Catalogue is the large number of observations that has been obtained, the Right Ascensions of over 420 stars being deduced from at least 10 observations of each star. Professor Safford has appended to the Catalogue a very useful Table of the Annual Terms of the Standard Polar Stars.

* Professor Safford states that one object he had in view was the detection, if it existed, of a periodic error of rather complex form in Carrington's Right Ascensions, first suspected by Professor Benjamin Peirce, and published by him in *Gould's Astronomical Journal*, No. 114, vol. v., p. 137. As this journal is rather scarce, we give a brief quotation from Professor Pierce's paper. In comparing Carrington and Schwerd, he says: "Mr. Carrington's polar distances are upon an average $0''\cdot75$ less than those of Schwerd. This diminution of polar distance is not restricted to the stars in any especial locality, although it is rather larger for the stars which are more remote from the pole, and for those stars which are between 12^{h} and 18^{h} R.A. Mr. Carrington's Right Ascensions are also greater than those of Schwerd, and the difference is so great that when multiplied by the cosine of the declination it is on the average more than a second of arc."

Octant of α.	Mean Excess of Carrington's Polar Distance.				Mean Excess of Carrington's $\alpha \cos\delta$.			
	0° to 3°.	3° to 5°.	5° to 7°.	7° to 9°.	0° to 3°.	3° to 5°.	5° to 7°.	7° to 9°.
1	+0·31	−0·67	−0·45	−0·68	+1·20	+0·77	−0·09	+1·21
2	+1·30	−0·88	0·66	0·35	+0·50	1·46	+2·14	1·48
3	−0·06	+0·31	1·13	0·42	−0·01	0·03	0·99	0·78
4	0·54	−0·35	0·98	0·53	−0·12	1·00	1·09	1·66
5	0·06	1·52	1·30	2·04	+0·49	0·22	1·44	1·53
6	1·54	1·09	1·34	1·59	0·00	0·78	1·45	2·00
7	1·08	1·01	0·53	0·45	+1·07	0·84	0·94	1·23
8	−0·97	−0·51	−0·73	−0·37	+1·33	+1·67	+1·32	+0·74

Vol. ix. of the *Annals*, published in 1878, is devoted to the "Photometric Researches of Professor C. S. Peirce," a notice of which will be found elsewhere.

Vol. x., published in 1877, consists of "Observations made with the Meridian Circle during the years 1871 and 1872, under the direction of the late Professor Winlock, by Professor W. A. Rogers."

The Meridian Circle with which these observations were made has an object glass of 8·25 inches aperture, and 9 feet 4·4 inches focal length. The collimators have apertures of 8 inches and focal lengths equal to that of the chief telescope. The diameter of the circle is 3 feet and the length of the axis 4 feet. In the transit reticule a system of lines etched upon glass has been substituted for spider lines. The result of observations made for the purpose of ascertaining the amount of the loss of light from using glass was, that when microscopic cover-glass was employed it was imperceptible to the eye. All the wires (lines) used for transits are double, the star being observed when it is in the centre, between the lines. Professor Rogers remarks that the result of this is a slight diminution of the probable error of observation.

The observations, which are entirely differential, consist of the positions of 564 stars, of which 289 are found in the Catalogue of the *Astronomische Gesellschaft*. These primary stars furnish the positions upon which the remaining 275 secondary stars depend. We have, at pp. 201–211, Catalogue 1 of the 289 primary stars, giving their mean Right Ascensions and Declinations derived from the observations, with their annual variations for the epoch 1872·0, together with a column of corrections to the Catalogue of the *Astronomische Gesellschaft*. Catalogue 2, pp. 213–227, gives the mean Right Ascensions and Declinations for 1872·0 of the 275 secondary stars, derived from the observations, with their precessions and secular variations, and proper motions. The column of observations shows that a fair number in each element has been obtained. The original observations from which these Catalogues have been deduced are contained in pp. 1–199.

In discussing the proper motions, Professor Rogers commences by reducing to a homogeneous system in Right Ascension and Declination the various Catalogues compared; the standard system of Right Ascensions being that derived by Professor Newcomb, and published in *Washington Observations*, 1870, Appendix III., and for standard Declinations, those furnished by the *Astronomische Gesellschaft* for the reduction of the zone observations. Pp. xxxv.–xxxvii. give a most valuable series of equations for reducing each Catalogue of Right Ascensions to Professor Newcomb's system; being an extension of the corrections given by him at p. 43 of his Memoir, referred to above, which were limited to equatoreal and zodiacal stars. A complete discussion is also made of the corrections and residual

in Declination to the various principal Catalogues. A novel and interesting treatment of this question is afforded by Professor E. C. Pickering, the present Director of the Harvard College Observatory, at pp. lvi.–lxvii., in a *Graphical Discussion of the Residuals in Declination*. A plate of graphic curves afforded by the Residuals in Declination of each Catalogue is given, in which the Declinations form the abscissæ and the deviations the ordinates. Taking the average of the residuals of all the Catalogues for the three periods, Bradley 1755 to Cambridge 1845, Greenwich 1845 to Harvard College 1872, and Bradley 1755 to Harvard College 1872, there is a very striking similarity in the form of the curves. From this discussion Professor Pickering derives Tables of corrections to the Right Ascensions on account of errors depending on the Right Ascension, and on the Declination, and a Table of the "Systematic Corrections to be applied to observed Declinations."

The above full discussion of this important subject will be highly appreciated by astronomers, and their labours in the determination of proper motions will be thereby much facilitated.

Appended to this volume is a Catalogue of the Mean Right Ascensions for 1868·0 of 604 Stars observed with the old Transit Circle, made and reduced by Mr. E. P. Austin, a large proportion of which appear to be dependent on single observations.

Mr. C. S. Peirce's Photometric Researches.

The Observatory of Harvard College has devoted the ninth volume of its *Annals* to the Photometric Researches of Mr. C. S. Peirce, which consist of a very valuable and elaborate investigation in this interesting but somewhat neglected branch of astronomy.

These researches were made by Mr. Peirce in the years 1872–1875, while engaged on the U. S. Coast Survey. At the instigation of the late Professor Winlock, a Zöllner's Astrophotometer was obtained for the Harvard College Observatory, and the author, who was temporarily appointed to duty there, was directed to prepare and carry out a plan of photometric observations. These appear to have been made at various stations of the U. S. Coast Survey, where the author happened to be located, and the resulting work, being submitted to Profesor Winlock, was accepted by him, and hence its appearance in the *Annals* of the Observatory of which he was the late Director.

An interesting chapter on the "Sensation of Light," and the different sensibility of the eye to lights of different refrangibilities, forms a fitting introduction to so elaborate a work on Photometry.

In chapter ii., "On the numbers of Stars of different degrees of brightness," the author explains his "method of equable distribution" which he has adopted as the basis of a system of star magnitudes. He says (p. 9), "If one observer says there are nine 1st magnitude stars in the northern heavens and another finds only eight, clearly the latter consigns some star to the 2nd magnitude which the other considers to be of the 1st, and therefore he makes the limit between the 1st and 2nd magnitudes to be brighter than the other makes it. Suppose that neither of two observers made any errors in his estimations, and that their discrepancies arose solely from the differences of their scales of magnitudes; then, if they observed the same stars, whichever had fewer stars brighter than the 4th magnitude, for example, would have made the limit between his 3rd and 4th magnitudes the brighter. In fact we might call these numbers a scale of magnitudes. If there were 175 stars brighter than the 4th magnitude, we might say that the limit between the two was, upon this new scale, the 175th magnitude." To determine his "scale of equable distribution" he further says, "I count all the stars which an observer finds of each magnitude in the northern heavens. Denote the sum of these, or the number as bright or brighter than each magnitude by $\nu(m)$. Then, for the scale of equable distribution, the numerical magnitude being m, we have

$$m = -\frac{1}{3} + 1{\cdot}892958 \log \nu(m).$$

In this way we shall obtain the magnitudes upon the scale of equable distribution of the limits of each class in the scales of the different observers."

Adopting this principle, Mr. Peirce proceeds to reduce the magnitudes in the following Catalogues: *Durchmusterung*, *Uranometria Nova*, Heis' *Atlas Cœlestis*, Ptolemy, Al Sûfi, Ulugh Beigh, Tycho Brahe, Hevelius, William Herschel, Zöllner, John Herschel, Seidel, and Behrmann; the discussion of each Catalogue being followed by a Table for the reduction of its magnitudes to the scale of equable distribution.

The *Durchmusterung* is considered by the author one of the best collections of star magnitudes we have, and he publishes a count of the stars of each tenth of a magnitude in this Catalogue. In discussing Heis's Catalogue, a long list of errata and corrigenda is given at p. 29, but the author has omitted to notice the extensive list of errata in this Catalogue by Tromholdt, published in vol. ix. of the *Vierteljahrsschrift*.

A very valuable analysis of the magnitudes in the principal MSS. and editions of the *Almagest* is given at pp. 36–46, the result of considerable labour. Pp. 57–83 contain all Sir William Herschel's star magnitudes arranged in groups.

This interesting and elaborate reduction of magnitudes to a uniform system occupies nearly half the volume; it is followed

by chapter iii., containing the original observations with a Zöllner's astrophotometer. The principle of this instrument is, that an artificial star is thrown into the field of a telescope, and its brightness is reduced by the rotation of a Nicol prism until it matches in brightness any real star which is in the field at the same time; the artificial star being produced by the flame of a kerosene lamp. A Table at p. 91, giving the magnitude of this artificial star for various dates throughout the period of observation, shows that the intensity of the lamp was liable to considerable fluctuations.

Various difficulties in observing are described and discussed, the author mentioning that the most difficult part of the observations with the instrument consists in putting the eye straight to the telescope. This is a difficulty which is peculiar to all photometric observations, and especially so in the method of limiting apertures.

Mr. Peirce's design was to obtain the magnitudes of all the stars in Argelander's *Uranometria Nova* between 40° and 50° of north declination, consisting of 368 stars; but about 100 additional stars were subsequently added to the programme. The stars were divided into 70 groups, "each consisting of neighbouring stars, these groups lying in two zones, and so that the boundary between two adjacent groups of either zone should have as near as possible the same right ascension as the middle of a group in the other zone. Each set of observations consisted in comparing the stars of two groups with the photometer star, thus comparing these groups with one another."

The observations having been completed, all the photometer readings were separately reduced to a scale of magnitudes, adopting a light ratio = 2·25. Lastly, the magnitudes of 340 stars were compared with the reduced magnitudes of the *Durchmusterung* to reduce them to that scale of equable distribution used in the comparative catalogue; for this scale the light ratio was found to be = 2·565. Pp. 128–138 contain a catalogue of 494 stars observed by the author, with the magnitudes computed by him compared with various authorities.

A cursory comparison of the author's results with the magnitudes of the *Durchmusterung* at once shows a marked discrepancy, which further examination suggests to be dependent upon the right ascension. In R.A. 0^h–12^h Mr. Peirce makes 66 per cent. of the stars brighter than they are given in the *Durchmusterung*, whereas in R.A. 12^h–24^h only 24 per cent. are brighter. Further on, at p. 171, where the author proceeds to discuss the probable error of his magnitudes, he finds the correction to them expressed by the following formula:—

$$-0^m{\cdot}04 + 0^m{\cdot}24 \sin (\alpha + 1^h\ 11^m).$$

It is stated in the concluding chapter, "On the form of the Galactic Cluster," that "the chief end of observations of the

magnitudes of stars is to determine the form of the cluster in which our Sun is situated." But this rather begs the whole question. If the stars were all of a uniform size, and their light, or magnitude, were proportional to the square of their distances, photometry would necessarily reveal the form of the solar cluster; but we have yet no direct evidence of this. It would seem that stellar photometry is much hampered by certain assumptions which are thought to be necessary and convenient; for instance, that the relative brightness of stars is dependent on their distance, that the faintest naked eye stars should be of the 6th magnitude, and that the light ratio for bright stars should be of a different value to that for telescopic stars. It is to be regretted that astronomers have not agreed upon a definite light ratio. Stampfer's determination of R, which was adopted by Argelander, = 2·56, for which Pogson substituted 2·512, because the logarithm = 0·4000. Seidel's results from stars down to $3\frac{1}{2}$ mag. give R = 2·789; Steinheil, using the same instrument as Seidel, R = 2·819; Zöllner, with naked-eye stars, finds R = 2·427; Dr. Rosén's observations give R = 2·339, with an appearance of a larger value for the brighter stars; and Mr. Peirce gives log ρ = 0·486 − ·0162 m., which produces this series of light ratios for the several magnitudes :—

Mag.	
1	R = 2·950
2	= 2·842
3	= 2·738
4	= 2 638
5	= 2·541
6	= 2·448
10	= 2·109.

This is most unsatisfactory, and it does not seem that our knowledge of the photometry of the stars can be much advanced till an understanding is arrived at among astronomers on this important point. Exception may also reasonably be taken to Mr. Peirce's method of equable distribution; on the face of it, it is impossible it can be a true photometric scale, and it is really condemned by the author himself, who states (p. 170) that the discrepancies between Zöllner and himself must "ultimately be ascribed to the fact that the scale of equable distribution of chapter ii. is not an equiphotometric scale."

Still, the importance of Mr. Peirce's work should not be underrated; a more perfect scale may be used in reducing the original observations contained in this volume, and his labours may result in a series of magnitudes of far higher value than those given on his adopted theory.

Double Star Observations of the Lund Observatory.

A valuable contribution to double star astronomy was published in 1876 in vol. xii. of the *Lunds Universitats Årsskrift*, entitled, "Mesures Micrométriques d'Etoiles Doubles faites à l'Observatoire de Lund, suivies de notes sur leurs mouvements relatifs, par N. C. Dunér. Lund, 1876."

These observations were made in the years 1867 to 1875 with an equatoreal telescope by Merz of 9·6 inches aperture and 14 feet 1 inch focal length, or exactly the same size as the great Dorpat telescope. The measurements were made with a filar micrometer by Jünger, of Copenhagen, in which only one wire is movable. All position angles were measured by Professor Dunér, who followed the advice of Professor Otto Struve, by placing the double star between the wires separated from it by several seconds; and in measuring distances two measures were always taken, turning the micrometer screw first in one direction and then in the other.

The observations consist of measurements of distances and position angles, and estimates of the magnitudes of 442 double stars, mostly from W. Struve's Catalogue; approximate positions are given for the epoch 1870·0, with brief notes of the colours of the stars and a numerical indication of the state of the atmosphere.

The second part of the Memoir is devoted to notes on the relative motion of all the double stars of which measurements are given in the first part, and forms a pretty complete history of each double star. In discussing the measurements of double star observers, Professor Dunér gives the highest weight to those of W. Struve. The author has appended to his Memoir a Table, in which he has classified the double stars from the Dorpat Catalogue, measured by him, according to the extent of their relative motions: Class I. consisting of stars which have made a complete revolution since they were first measured; Class II. stars which have moved through 180° of their apparent orbit; and so on to Class IX., which consists of stars which appear to be only optically double.

One commendable feature in this important work on double stars is that it is not in Swedish; the author, to render his labours more widely available, has written it, in what is to him a foreign language; an example which we could wish were more commonly followed by some European academies whose languages are not generally known or studied.

Report on the Progress of Meteoric Astronomy during the year 1878 by Professor Alex. Herschel.

The past year has been one of great activity both in developing the theory and in extending the observations of meteors and meteor showers. To describe more than the principal of its meteoric occurrences would form too long a narrative to be suitable for this Report. The short review which follows of the past year's observations and researches relating to meteoric apparitions is therefore confined to recording some of the chief meteoric events which have taken place, and to reviewing very briefly some of the most important work which has been accomplished during the past year, in discussing observations, and in improving our knowledge of the theory and of the probable history and origin of meteoric bodies.

Aërolites.—A stonefall took place on October 13, 1877, near Alexinatz, a town on the Bugarska (or Morava) river, in the south-eastern part of Servia, specimens of which have been preserved and will be submitted to proper analysis and examination. A small stone is also related to have fallen on a house at Butzbach in Hesse, from a meteor which appeared on the night of August 21, 1878, and to have been presented to the Berlin museum; but of its aërolitic character no other information or authentic indication has yet been received.

Several mineralogical examinations of meteorites of great interest and completeness have been carried out, of which some of the most important examples and particulars may be thus related. In connection with that made of the Ställdalen meteorites (Sweden, June 28, 1876) by Professor Nordenskjöld, he has observed that some eight or nine meteorites, among many which appear to be entirely unconnected with each other in their dates of apparition, form with the Ställdalen ones a well-marked group, apparently individual and distinct, but which, Professor Nordenskjöld observes, will probably be found to be only one among many similar groups of aërolites which will hereafter be detected.* The distinguishing character of this group's chemical composition is the proportion by weight of silicon, and of the metals with which it is associated, in their elementary or unoxidised forms, the average percentage proportions of these elements in the *Hessleïtes*—as the group is designated, from the place of fall of one of its most important members—being with exceedingly small variations seldom amounting to 1 per cent., about

Silicon.	Magnesium.	Iron.	Nickel.	Calcium.	Aluminium.	Sodium.	Other Metals.	Total.
26·6	21·8	43·7	2·8	1·9	1·5	1·0	0·9	100·2

* *Transactions of the Geological Society of Stockholm*, 1878, No. 44.

The other metals, present in only minute quantities, so as to be not always detected in the several meteorites like the rest, are potassium, cobalt, manganese, chromium, and tin. The actual states of oxidation and combination in which this mixture of metals is found in the several aërolites of the group result, as Professor Nordenskjöld conjectures, from a series of oxidising and reducing influences to which they have been in turns subjected, among which a reducing action producing the metallic iron appears, from the microscopic injection of this metal (alloyed with nickel) into every part of the structure of the stones, to be the final or most recent stage of the processes which they have undergone. Monsieur Stanislas Meunier has shown * that the action of hydrogen on mixed chlorides of iron and nickel at a red heat is to form, by their reduction, a crystalline alloy of these metals intimately pervading and solidly cementing together stony fragments placed in them into a hard mass, the crystals of which resemble the crystalline varieties of the same alloy found in siderites, and which show to some extent, by section and etching the well known Widmanstättian figures which characterise meteoric iron.

That the operation of some similar conditions has produced in certain ancient lavas of our own globe considerable quantities of terrestrial "native" or metallic iron is now a thoroughly well determined fact, from the concurrent testimony of many observations and researches. The detection of the native metal by Professor Andrews in the Irish basalts, corroborated in those of Bohemia by Professor Reuss,† assumed quite recently a fresh significance from the recognition also, by Monsieur Daubrée, of native or metallic nickel-iron as an alloy with platinum in certain rocks ("Dhunite") resembling serpentine, or magnesian silicates.‡ But its detection in visible grains in the basalt or lava rocks of Assuk, Disko Island, a part of the same basaltic range, although 100 miles from the spot, of Ovifak, in Greenland, where Nordenskjöld's discovery of the vast masses of metallic iron was made, together with other evidence collected in two visits to the same district by Professor Steenstrup, of Copenhagen,§ have latterly most strongly supported this conclusion that metallic nickel-iron is an abundant native product in some terrestrial lavas.

Pursuing this investigation to its close by analysing and

* *Comptes Rendus*, vol. lxxxvii., p. 855, December 2, 1878.

† "Address to the British Association, Dublin, 1876," by Dr. Andrews, vol. of the *British Association Reports for* 1876, p. lxxiii.

‡ *See* the last of these *Reports*, these *Notices*, vol. xxxviii., p. 220, last note of the page.

§ *Om de kulförende Dannelser paa Öen Disko &c.*, Copenhagen, 1874; and *Om de Nordenskiöldske Jærnmasser &c.*, Copenhagen, 1876, by K. J. V. Steenstrup, with a map and coloured plates. A translation into English of M. Steenstrup's Memoir has been published by M. Roche, one of his companions in his expeditions, who has now returned to Greenland for further explorations.

comparing together the materials collected on the spot and sent to him for this purpose by the different explorers of this district, Dr. Lawrence Smith has now amply shown, by a variety of proofs and comparative analyses,* not only that the celebrated masses of nickel iron of Ovifak are without doubt of terrestrial origin, but also that many smaller iron blocks discovered on the east and west coasts of Greenland by successive navigators (those recorded by Captain Sir J. C. Ross among the number) resemble each other and the Ovifak iron remarkably, while they differ essentially from meteoric iron by the large proportion of combined carbon in their composition. These scattered iron masses have been found at places on the east and west coasts of Greenland which are entirely confined to a region between the parallels of N. latitude 69° and 76°, where the coast is basaltic, and, like the larger masses found in the same region by Professor Nordenskjöld, Dr. Lawrence Smith now shows conclusively that they are all geological productions of the immense lava field which covers to an enormous (and northwards to an unknown) extent the greater part of northern Greenland.

The process of reduction to which the metallic masses owe their origin is ascribed in the Memoir to the beds of lignite and to vegetable remains in the strata which the immense tracts of lava overlie. From this view, which is not a less probable one than the supposition which he himself had formerly advanced—that metallic iron reaches the Earth's surface associated with basic igneous rocks, from depths in which it is naturally metallic and unscorified—Monsieur Daubrée, in his review of the Memoir, finds no reason to dissent; his own experiments having, in fact, already proved † that such terrestrial rocks (selected as presenting the greatest similarity to stony meteorites) are reduced by fusion, in charcoal-lined crucibles, with formation of metallic nickel-iron; and indeed that they crystallise on cooling into aggregates of their component minerals, hardly distinguishable from separate crystallisations of the same minerals which occur in meteorites. But the large quantity of graphite and of combined carbon found in the Greenland iron masses distinguishes them from meteorites, and probably shows that it is mainly to the action of carbonaceous gases and substances upon their fused materials that the natural smelting process which these lavas have undergone must be ascribed.

Comets.—Leaving to mineralogists and comparative geolo-

* In a paper accepted for insertion in the *Mémoires des Savants Etrangers*; *see* Dr. L. Smith's abstract of the Memoir in *Comptes Rendus*, vol. lxxxvii., p. 674, and M. Daubrée's report and observations on the paper, *Ibid.*, p. 911.

† *Comptes Rendus*, vol. lxii., pp. 200, 269, 660, Jan. 29—March 19, 1866; and *Bulletin de la Société Géologique de France*, vol. xxiii., p. 291, 1866. A detailed account of M. Daubrée's experiments on the artificial production of meteorites, as described in these papers, will be found in the *British Association Reports*, vol. for 1868, p. 415.

gists*—as Professor Newton does in an important mathematically and philosophically conducted Essay which he has lately published † on the almost inscrutable question of the distant birthplace and primitive fields of revolution of periodical and non-periodic comets—the much more mysterious question of how these bodies were consolidated in those regions into the nuclear orbs or parcels of fragments from which it seems not improbable that the coherent masses of aërolites and shooting stars are detached, we may welcome the new researches of the renowned explorer of the November meteor-stream as a much needed contribution towards a final solution of the immensely large and apparently space-pervading problem of celestial mechanics which he has attempted to resolve.

Two, if not three classes of comets, it seems probable from the discussion, although not presumed to be certainly distinct, may present themselves for observation: those of very short and those of much longer (it may sometimes be only suspected) periods of revolution, both of which classes may possibly (but not necessarily) have had their origin, like the asteroids, in the contraction of the solar nebula. Regarding a third and much larger class however, from a discussion of the inclinations of their orbits, Professor Newton is led to the conclusion by various considerations, among which the prevalence of large inclinations of the orbits may principally be noticed, that such an explanation of the origin of the major and principal part of the observed cometic orbits is far from being easily reconcilable with the existing data; and that the cometic hypothesis of Laplace, which regards them as bodies foreign to, and, in their motions and primitive history, independent of the solar nebula, is, on the contrary, well borne out by the collective examination. A rather larger number of the steepest comet-orbits are found with inclinations a little exceeding, than with those a little less than 90°; but the visibility of comets, regarded as accidental visitors in the solar system, is almost entirely dependent, as Laplace has shown, upon their pursuing towards it nearly parabolic orbits; and agreeably to this consequence of the theory of probability, certainly recorded cases of comets with decidedly hyperbolic orbits are extremely rare. In the course of an unknown and prodigious lapse of ages, as suggested by Professor Newton, a certain number of comets with apparently parabolic paths may have accumulated upon our list, and may have been deflected from more rapid courses into some which are either nearly or may be actually (although not perceptibly so to our observation)

* *Cours de Géologie comparée*, Paris, 1874, is the title of an introductory lecture-course on geology at the Muséum d'Histoire Naturelle, in Paris, by M. St. Meunier, in which all the results of his own and M. Daubrée's researches on meteorites are related in a clear, copious, and collective form.

† "On the Origin of Comets," by H. A. Newton, *American Journal of Science*, vol. xvi., p. 166, September 1878.

closed curves. The effect of the planetary perturbations by which the speed of some external comets has thus probably been arrested is in general to increase the inclinations, especially of steeply described orbits, and thus a slight anomaly which the curve of frequency of the orbit inclinations exhibits in that part of its range is satisfactorily explained.

The evidence so strongly and distinctly shown in favour of the theory of the original motion of most, if not of all, of our recorded comets in spaces far external to the solar nebula rests upon the assumption that the comet-yielding matter of the primitive nebula, if it existed, was confined, like that which formed the planets, to the neighbourhood of the ecliptic plane. This ground of the conclusion may admit of an exception that a similar distribution of the inclinations of the orbits to that which Laplace's hypothesis requires would have been produced were this matter otherwise spread uniformly on a very distant sphere, instead of in the distant portions of a disk or annulus. But the plan of the planetary motions in the solar system, and the analogy which they present to spiral and disk-like nebulæ in the heavens, scarcely allows us to assume with reasonable probability such a different disposition of the matter of the outer part of the nebula from what the courses of the planets show us must have been its original mode of distribution and of gradual contraction near the centre; and with no evidence before us of the past or present existence of a distant spherical envelope of nebular matter enclosing the solar system, we may certainly prefer to accept, with Professor Newton, the much simpler conclusion to which he is finally conducted by his well executed labours, that, with the exception of a few, perhaps, of the zodiacal comets, and comets of the shortest periods, all the comets which have been recorded are originally denizens of the interstellar spaces, pursuing unknown orbits like the stars, and separated, at least, and dissevered in their primitive astronomical relations from any connection with the nebular matter which, in the process of concentration supposed by the nebular hypothesis, formed the Sun, the planets, and the asteroids.

Meteors and Meteor Showers.—It was by a close and critical examination of the observed course and extent of the change known as the diurnal variation of the rate of frequency of ordinary shooting stars that an approximately correct knowledge of the real forms of the orbits of shooting stars was first obtained, and that the large excentricities or elongations of these orbits, and their resemblance to the orbits of comets was first shown by Newton and Schiaparelli. But a closer inspection of the known curve of diurnal variation as recorded by Coulvier Gravier, and by Schmidt and Zezioli, with all the new developments which the established theory of meteor showers has since then received, now leads Professor von Niessl, of Brünn, by an exact comparison of the theory with the observations, to a rather

different result.* It is not, in fact, single bodies reaching his standpoint from all surrounding directions, but flights of meteor particles parallel to such lines, or to such axes of radiation of their diverging streams, which invade the whole visible extent of an observer's horizon, and require him to register their numbers. Supposing the original directions of these axes to be evenly distributed, and the streams themselves to be originally of equal closeness or richness along their several axes, the effect of the Earth's speed of motion through them will not only be to cluster the radiant points together, but also to increase the apparent richness of the individual streams round the apex of the Earth's way. In the same way, neighbourhood of a radiant point to an observer's zenith renders the apparent abundance of its stream much richer than when the radiant point is near the horizon. Giving these and similar allowances due consideration, it appears that, on the average of the whole year, a morning maximum of meteoric frequency about three times greater than the mean midnight frequency (instead of scarcely $1\frac{1}{2}$ times as great, as observed) should be expected, and the hour of maximum abundance should be at 6 o'clock; while, by common consent of the three recorded curves of frequency, it takes place at about 3^h A.M. It is not possible to remove this last discrepancy, as Professor von Niessl shows, by substituting for the parabolic velocity of the modern meteor theory any different average velocity of shooting stars; nor is it a possible effect of daybreak (known or unknown to the observers), which is excluded by the proper treatment of the observations. But it may be suggested that a simpler, and perhaps sufficient, explanation of the difficulty will be furnished by a certain superabundance of radiant points above what an originally even distribution of them would require, which is found in the catalogues (according to a Table of some of them arranged to show this by von Niessl) near the antiapex of the Earth's way. The setting and cessation of these radiant points soon after midnight may perhaps cause the growing rate of frequency of shooting stars up to the first two or three, to abate again considerably in the later morning hours. The motions of periodic comets, especially of those with short periods, are in general direct, and the inclinations of their orbits to the ecliptic are for the most part inconsiderable; in their frequent approaches to the Sun, the disintegration of these comets into closed and continuous meteor streams also proceeds more rapidly than in comets moving in less restricted or much longer-cycled orbits. That a preponderance or undue abundance of meteors and meteor showers overtaking the Earth and falling upon it from the region round the antiapex should be discovered both in the fullest catalogues of meteor showers, and, as it seems possible to recognise also, in the marked peculiarity of the time of the

* "Ueber die tägliche Variation der Sternschnuppen," von Prof. G. v Niessl, in Brünn; *Astronomische Nachrichten*, No. 2222, vol. xciii. p. 209, Oct. 14, 1878.

morning maximum frequency of shooting stars, appears accordingly to be in very good agreement with what the existing astronomical theory of their origin would lead us to expect.

In the course of calculations of the real paths of many recent fireballs, such close and frequent repetitions in the positions of some of their radiant points have been noticed by Professor von Niessl as to induce him to give this observation some attention. Many very striking and remarkable cases, even exhibiting a certain regularity in the time of inactivity intervening between two successive resuscitations of a radiant point, have been similarly noticed among ordinary meteor showers by Mr. Denning.* With regard to these occurrences of concentric meteor flights, von Niessl remarks that, in any theory of physical connection which may possibly be projected to account for them, the condition of their pursuing orbits, which, in extent and excentricity, present even distant resemblances to parabolas,† must be rejected, and regarded as an inadmissible hypothesis. A single example from among the long list of instances produced by Mr. Denning will show the complete baselessness of any project for connecting together physically, with orbits at all resembling those of comets, two pretty nearly identical meteor showers as they are instanced by Mr. Denning, and as they are currently regarded in many radiant lists.

☄ 1680 ♋, Dec. 26, 132+21·5.	☄ 1833 ♈, Jan. 27, 135+25.
Dec. 21—Jan. 5, 130+20; Denning, 1876–77 (a feeble shower).	1877, Jan. 19, 135+27 (±5°) (Large fireball seen in Ireland and the West of England.)
	Feb. 13, 133+26; S.Z. 32.

Of the two meteor observations here described, giving nearly recurring radiant points in *Cancer* near the beginning and end of January 1877, the first is an expiring shower of the "October—December Cancrids," diverging from that place, and the second is nearly identifiable with the first approach of the second display of the "February—April Cancrids" at the same place as the centre of the former group. Two comets with parabolic orbits are also so nearly concentric with these two meteoric systems as to be practically identifiable with them; but, owing to the difference of about thirty days between the dates of their two nearly concentric radiant points, no two parabolic orbits more widely dissimilar or more entirely disconnected from each other could very well be selected. Each of them nearly crossing the Earth's orbit, the comet of 1680 almost grazed the Sun's surface in a plane steeply inclined to the ecliptic before returning to the depths of space nearly upon its former track; the comet of 1833, moving almost in the ecliptic plane, overtook the Earth, crossed its orbit in a wide sweep to the other extremity of a

* These *Notices*, vol. xxxviii. p. 111, Jan. 1878.

† Or, it might be added, "to conic sections round the Sun." [G. L. Tupman.]

diameter drawn through the Sun, where it again encountered the Earth's orbit even more closely than before, having never approached much nearer than to mid-distance of the Earth's orbit from the Sun. But this is not an exceptional example; it is, on the contrary, a common instance of the alteration in a parabolic orbit which even a few days' interval suffices to produce in concentric comet radiant points and meteor showers. To discover a physical connection between the comets of 1680 and 1833 would be nearly as impossible as to track them both through their entire revolutions; and if concentricity of successive showers is a proof of their physical connection, it must be owing to a very different class of orbits from those of comets being the real paths of revolution of a rather large proportion of the streams or systems of ordinary shower meteors which have been observed.

Among the many dissimilar kinds of bodies which it is thus not at all improbable may be circulating in the solar system, one of the meteors described in the accompanying list of fireballs whose real paths have been determined, observed by Captain Tupman on the night of the 27th of November 1877, must here be prominently noticed as occupying a very singular position.* The simultaneous observations of its apparent course at Greenwich and at Writtle (fully confirmed by one obtained at Bristol) perfectly define the real height, locality, and direction of the meteor's motion, and its length of path. At the same time, its aspect to the observers was one of the most remarkable, by its slowness and duration, which fireballs sometimes, but not very commonly, present. Its stately course of 30° or 40°, in which it was, towards the end, about as bright as *Venus*, occupied not less than seven or eight seconds at Writtle (where a part of it near the close seems to have escaped observation), and fully 15 or 20 seconds at the Royal Observatory, Greenwich, where, as it faded out at last, Captain Tupman observed it moving there with extreme slowness. It began as a small shooting star, and was only white and brilliant in about the last quarter of its track, with a red spark-train, but leaving no permanent light streak visible upon its course. From its real altitude of 56 miles above the east point of Kent to 14 miles above a point near St. Omer, on the French coast, the relative velocity of its motion cannot have appreciably exceeded 5 or 6 miles per second. But the direction of its relative motion being at the same time just perpendicular both to the Earth's path and to the plane of the ecliptic, its velocity in that direction could not have been less than about 19 miles per second if its real orbit had been parabolic. The real velocity of the meteor in its orbit was accordingly only $19\frac{1}{2}$ instead of 26, or *not so much as one mile*, instead of nearly eight miles, per second greater than the Earth's, as it should have been had the meteor's orbit been a very long elliptic or a parabolic

* "On a Meteor of Short Periodic Time," by Captain G. L. Tupman, *British Association Reports*, vol. for 1878, "Report on Luminous Meteors," Appendix II., Large Meteors.

one. It must, on the contrary, have been very nearly circular, and by calculation the following elements of it have been obtained by Captain Tupman, showing that the major axis, excentricity, and plane of the real orbit are not extremely different from those of the orbit in which the Earth revolves round the Sun.

$q = 0{\cdot}9858$	$\pi = 70^\circ\ 6'$	Motion direct.
$\epsilon = 0{\cdot}1568$	$\Omega = 245\ 50$	Periodic time 462 days.
$\phi = -4^\circ\ 16'$	$i = 15\ 0$	

It will be interesting to notice if other orbits of fireballs similar to this one will hereafter be observed, which appears to indicate that a ring of minute bodies, not unlike the system of the asteroids, may be accompanying the Earth upon its track.

The other fireballs of the accompanying list were for the most part widely observed, and their real paths have been pretty reliably determined. Those of the detonating meteors of December 24, 1873, and August 11, 1878, by Messrs. Cleveland Abbe,* and Daniel Kirkwood † in America; those of the meteors of December 9, 1877, and April 2 and November 18, 1878, by Captain Tupman, and Professor Herschel; and those of large fireballs on March 25, May 12, June 7, and July 29, 1877, by descriptions of their appearance in England, which are there compared together, in the Report for 1878 of the Luminous Meteor Committee of the British Association. The roughly observed relative velocities of these meteors are compared in the Table with the theoretical or parabolic ones, and in its last column the Table also shows the nearest known meteor showers or comet orbits with which the rare spectacles which these large meteors presented appear to have exhibited, in the positions of their radiant points, some traces of resemblance.

* Report of the Committee to collect information relative to the Meteor of December 24, 1873. (Committee: Peter Parker, Cleveland Abbe, W. L. Nicholson). *Proceedings of the Philosophical Society of Washington*, vol. ii., p. 139, April 7, 1877.

† *The Analyst*, Journal of Mathematics, vol. v., p. 178, Les Moines, Iowa, U.S., 1878.

Real Paths of Large Fireballs obtained from Duplicate Observations, principally in the Year 1878.

G.M.T. (or Local Time); Size, and other features of the Fireball's appearance.	Places of Observation.	Meteor's Real Course. Distances in British Statute Miles. Height and Locality of the Points of First Appearance.	Height and Locality of the Points of Disappearance.	Real length of Path and Speed of Motion.	Observed Radiant Point.	Nearest known Radiant Point, and Remarks.
1873, Dec. 24 ($7^h\ 39^m$ p.m. W.M.T.) Conical nucleus, brighter than full Moon; yellow, with short tail of red and blue sparks. Burst (?) with loud detonation; left no streak.	Washington, and neighbouring towns in Virginia and Maryland; and at Richmond, Newark, Danbury, &c., in the United States.	About 90 miles over a point near Newcastle, in the northern part of Delaware State, 30 miles S.W. from Philadelphia.	10, or 20 (?), miles over a point near Fairfax Cty., Virg., 30 or 60 (?) miles W.S.W. from Washington. Distance of the track from Washington, by the sound interval there, 31 miles.	Not definitely assignable, from the vagueness and conflicting nature of the data; probably about 120 miles in 3 to 5 seconds. (The parabolic speed is 35, and the observed speed probably about 30 miles per second.)	60° S. from N., alt. 25° by the mapped track. (Or at 115+38, near π, α *Geminorum*; but a possible range of the meteor's direction from about 113 ($\pm 3°$)+32 ($\pm 6°$) is admissible from the observations.)	[105+32, Nov. 23–Dec. 27, Geminids (Greg, 178); 108+36, Dec. 31, 1872, Denning (1876, *a*), 27; a radiant near *Castor*]. Account of the meteor (by a Committee of the Society), in the *Proceedings of the Philosophical Society of Washington*, vol. ii., pp. 139–161, with a map of the meteor's real course; April 7, 1877.
1877, Nov. 27, $10^h\ 26^m$ p.m. $\frac{1}{3}$ Moon's diam., in midcourse; blue, globular, with sparks; curved and extraordinarily slow motion, about 22 secs.	Greenwich, Writtle, and Bristol. (The appearance and real path of the meteor were observed and calculated by Captain Tupman).	56 miles; 11 miles north of Margate, Kent.	13 miles; 12 miles W. of St. Omer, France.	78 (± 5) miles in not less than 15 seconds. Velocity not greater than 5 miles per second. (Parabolic speed 19 miles per second.)	285 ($\pm 1°$)+64 ($\pm 5°$); at $\frac{1}{2}$ (δ, o) *Draconis*. Connection of the meteor with the stream of Draconids (Greg, 166, D.G. 3, Heis, D, and Schmidt) in Nov.–Dec. seems doubtful.	The real orbit must be nearly circular. Period about 500 days, motion direct, descending, inclination about 15°.
1877, Dec. 9, $8^h\ 12^m$ p.m. A fine meteor = 1*f*, with long course and streak; "mauve"-purple and green colours.	Royal Observatory, Greenwich, London, Bromley, and Writtle (Chelmsford). Three or four good observations compared together by Captain Tupman.	55 miles over Stoke Ferry, Norfolk.	36 miles over Stratford-on-Avon.	100 miles in three seconds by two estimates of the duration. Velocity 33 miles per second. (Parabolic speed 35 miles per second.)	112+27; between β and ι *Geminorum*. All the observed paths conform to it very nearly.	108+28, Dec. 9, 1877, Corder. A sharply defined radiant of streak-leaving meteors (of which this was one) apparently not Geminids, with long courses, not visible with the Geminids at 107+35 on the 10th.
1878, March 25, $10^h\ 22^m$ a.m. Large meteor in sunlight; conical, white, with red tail; burst, and left a smoke-wreath visible for 10^m or 15^m.	Dunbar, Dundee, &c., East coast of Scotland; and North of England.	50 miles; 30 miles E.S.E. from Berwick.	22 miles; 45 miles E.N.E. from Aberdeen.	130 miles in about 4 seconds (or 33 miles per second); not very certain estimations. (Agrees with the parabolic velocity.)	332−20 ($\pm 5°$); near ν *Aquarii*; 8° south of the ecliptic, and preceding the Sun's place 32° in R.A.	Very bright, near Dundee, even when passing close to the Sun. The perihelion distance of the real orbit is very small, = 0·02.

1878, April 2, $7^h\ 54^m$ p.m. Detonating fireball; $\frac{1}{2}$ Moon's diam.; red; slow, halting motion; burst into fragments.	Blackheath, Birmingham, and Leicester. Calculated path by Captain Tupman and Professor Herschel.	60 miles; 10 miles S. from Leicester.	15 miles (end-height very well determined); 5 miles W. from Coventry, 35 miles (agreeing with the time interval of the sound) from Leicester.	50 miles (beginning and length of path not very certain) in 3 or 4 seconds. (Agrees with the parabolic speed of 13 miles per second.)	177+49 (±3°); near χ *Ursæ Majoris*.	180+49, April 1–15, Heis, M. 7. A principal radiant of the April Ursids, whose streams are all nearly anti-apical.
1878, May 12, $8^h\ 53^m$ p.m. $\frac{1}{8}$ Moon's diam.; white, leaving sparks and a fragment near its disappearance. A detonation heard at Galashiels.	Edinburgh and the neighbourhood, in Scotland; York, and the North of England.	78 miles over Northallerton, Yorkshire.	17 miles over Boness, near Edinburgh; passing at a height and distance of about 34 miles nearly over Galashiels.	155 miles in about 10 seconds, reckoned, from several good estimates, for the whole flight. The parabolic velocity is 15 miles per second.	214−7 (±4°); near ι *Virginis*.	210−10, May, Denning 47 (1877), a rich, new shower. [Forshey, April 18, 1841, 198–8; exact radiant of a bright meteor shower. (*Am. Jour. of Sci.* vol. xlii. p. 395.)]
1878, June 7, $9^h\ 53^m$ p.m. $\frac{1}{4}$ Moon's diam.; blue, with reddish, flickering tail, and long, slow flight; left no streak.	South-western part of England; London, Kent, Shrewsbury, &c.	65 miles; 20 miles W.N.W. from Guernsey, Channel Islands.	37 miles; 15 miles E.N.E. from Lundy Isle, Bristol Channel.	160 miles in 8 or 9 seconds (by one good and several other estimates). Velocity about 19 miles, parabolic speed 20 miles per second.	247−25 (±5°); close to *Antares*.	248−20, fireball of June 17, 1873, Galle and von Niessl.
1878, July 29, $9^h\ 25^m$ or 30^m p.m. $\frac{3}{4}$ Moon's diam.; vivid white flash, and long spark-track; bursting at last; motion swift.	Manchester, Lancaster, and N. Wales and Cumberland.	82 miles; 8 miles W. from Manchester.	20 miles; midway between Preston and Blackpool, coast of Lancashire.	70 miles in about 3 seconds, by two estimates reckoned for the whole course. Velocity about 23 miles, parabolic speed 21 miles per second.	290 + 42 (or between 285+45 and 300+35, from the best recorded tracks); near δ *Cygni*.	284+44, end of July, 1878, Denning. A radiant point of some bright meteors.
1878, Aug. 11, about $10^h\ 10^m$ p.m. $\frac{1}{3}$ diam. of and outshone full Moon; greenish; burst into three red fragments, and detonated.	Bloomington, Indiana; Virginia and Pennsylvania. Notice and calculation of the meteor's path by Professor Kirkwood.	About 77 miles over the northern part of Western Virginia (350 miles due E. from Bloomington, alt. 10°).	15 or 20 miles (?) over Crawford County, Pennsylvania. Distance (by interval of the sound) west of Titusville, in that county, 25 miles.	About 170 or 180 miles in two seconds (an "uncertain" estimation); motion swift, and apparently hyperbolic (?).	Nearly horizontal and due south. But an exact position of the radiant point cannot be indicated.	*The Analyst*, U.S. Journal of Mathematics, vol. v. p. 178, Iowa, 1878.—The observations are few and incomplete, but difficult to reconcile with a parabolic speed of 20 miles (*circa*) per second.
1878, Nov. 18, $9^h\ 50^m$ p.m. A fine, slow-moving meteor, as bright as *Jupiter* or *Venus*.	Bristol and Writtle (Chelmsford). Real path calculated by Captain Tupman and Professor Herschel.	70 or 80 miles; midway between Nantes and Angers, France.	45 or 50 miles; midway between Le Mans and Laval, France.	About 70 miles. The duration of the meteor's flight was not recorded.	354+1, at λ *Piscium*. [The radiant point of 1743 I. (Clausen's) is in this constellation from the middle of the month of November to that of February.]	350+2, Dec. 1–2, 1877, Denning. A radiant of several slow meteors, one of them a fireball. 4+4, December, Schmidt.

The observations of shooting stars and new meteor showers, and also the reductions of the paths recorded in meteor catalogues, have been very actively pursued during the past year, in England by Mr. Denning, Mr. Corder, and by other observers, and on the Continent at some of the Astronomical Observatories, amongs others at Herr von Konkoly's private Observatory at O'Gyalla, who has now published a third Catalogue of Hungarian observations of about 250 shooting stars observed in the year 1877. From these abundant data, including, first, his own observations of the year 1877, Mr. Denning has formed two extensive Catalogues of carefully deduced shower centres, embracing, first, 162 meteor systems observed in that year by himself,* and, secondly, 316 radiant points obtained by reductions of eleven about fortnightly periods of observations of shooting stars collected by the Italian Meteor Association in the year 1872.† Of the new and valuable materials which these new lists contain it would not be possible to give a brief description here in the form of a serviceable abstract —the principal points of interest of each list have been detailed at considerable length in the past year's Report, for 1878, of the Luminous Meteor Committee of the British Association; but some of the observations made and of the results of the reductions were, from their striking and exact characters, of more than usual importance, and of these results a few particulars, with some remarks on later and not less striking and satisfactory meteor observations in the year 1878, at the conclusion of this Report, will here be briefly related.

Continuing a description of Mr. Denning's observations in the year 1877 from the partial summary of them already given in the last of these Reports,‡ the first showers of importance (besides January showers near γ *Eridani*, ν *Ursæ Majoris*, and ν, ψ *Cygni* on January 4, 15, and 17), detected by morning observations in the early part of the year, were three conspicuous ones on the morning of February 20, near α *Serpentis* (236+11), in *Coma* (281+35), and near ρ *Herculis* (263+36). The shower in *Coma* is concentric with radiant points well recorded at the same place by Greg, Tupman, and Schiaparelli in January; and it is not, therefore, necessarily to be regarded as identical with them). That in *Hercules*, although anticipated by a weak shower in the same constellation in January, is the first well-marked meteor system in the year proceeding from this constellation (just rising in morning watches, in the east), which later on furnishes the April "Lyrids" and circum-Lyrids from closely neighbouring positions. On March 14 a new A.M. shower of these early "Herculids" was noted at 263+48. The Cygnids also constitute a persistent series of showers in the same four months, but in lower declinations than the marked shower seen

* These *Notices*, vol. xxxviii., p. 303, March 1878.
† *Ibid.*, p. 315, March 1878.
‡ *Ibid.*, pp. 232–3 and 236–7.

in January in that constellation; and a shower of swift Antinoïds (Greg 56) was visible in the morning watches in both March and April, in the latter month during the period of the April meteor shower. During his watches for this special shower, on clear nights of April 16–19 (20 A.M.), the few Lyrids seen showed a radiant point at 269+37, while Mr. Corder noted at Writtle 13 Lyrids in about two hours on the morning of the 20th, with a radiant point at 275+35. Ten or twelve other meteor radiant points were found to be in contemporaneous activity, among which a conspicuous one of bright meteors near *δ Librœ*, at 228−2, confirms one of Mr. Greg's radiant points (G, 53, for April and May) at 227−5.

Projecting together a large collection of tracks (principally selected from the Austrian Meteor Catalogue of Dr. Weiss), directed on April 19–23 from regions east of *α Lyræ*, Mr. Denning deduced from them several definite radiant points,* and finds the place in *Cygnus* of the brightest contemporary shower of this period to be at 294+41. The "Draconids" (G, 64, near *o Draconis*) and a shower near 5 *Vulpecula* (20 meteors) were the next principal companion systems. Of the remaining 15 circum-*Lyra* showers, a pretty strong one in *Vulpecula*, at 312+22 (13 ↓s) may perhaps be associated in a parabolic orbit with the Comet 1790 III. (at 319+19, April 24), which passed at some distance (0·06) inside the Earth's orbit at its descending node. But a rather closer resemblance than this presents itself in Mr. Denning's own observations of the April period (April 16–19, 1877) of a shower near *δ Aquilæ*, not very certainly determined, at 286+5 (12 ↓s) with the hypothetical radiant point of *ℰ* 1844 II. (at 288+5, April 21), which passed at a somewhat greater distance (0·08) inside the Earth's orbit at its descending node.

Of such approximate agreements between theoretical, or parabolic meteor and comet orbits, a long list has now been collected, in which about 70 comets exhibit sufficiently close resemblances in their orbits to observed meteor streams to make further investigation and renewed observations of these meteor streams desirable, in order to decide on the reality of, and if possible to establish the connections. Such a list (to which a few supplementary additions might now be appended) was presented last year to this Society by the writer,† and it was published in the same number of these *Notices* as that which contained the above Paper by Mr. Denning on the April *Lyrids*. No cases of unquestionable agreement (excepting those of the four well-known comets of April, August, and November) can be discovered in the list; and recollecting that a simple radiant point, without other needful proofs for its interpretation, is not by itself sufficient to determine the nature and position of a meteor orbit, symptoms of

* "On the April Lyrids and Contemporary Meteor-showers;" these *Notices*, vol. xxxviii., p. 396, May 1878.

† *Ibid.*, p. 369, May 1878.

agreement much more certain than any which are presented in the list would evidently be required, before even the best examples which it affords could fairly be produced as certain cases of new discoveries of cometary meteor showers.

Among the meteor systems thus found to accompany the April Lyrids, Mr. Denning notices several reliable centres, and some suspected ones in the circumpolar constellations eastward from *Lyra*, of *Cassiopeia*, *Perseus*, *Auriga*, and *Camelopardus*, &c. A suspected shower of this group near *ζ Cassiopeiæ* (19+59, a point at *iota* of the same constellation having been already identified in March and April as a meteor-apex by Mr. Greg), coincides almost exactly with the observed direction (from 18+57) of two detonating fireballs seen in Austria and Bohemia on April 10, 1874, and April 9, 1876, as obtained by Professor von Niessl from careful investigations of their real paths.*

Mr. Denning and Mr. Corder also recorded, in April and May 1877, a well-marked and pretty active shower of bright meteors at about 207−8, between the stars *Spica* and *ι*, *κ Virginis*, a radiant point which is nearly on the ecliptic, and which also coincides very nearly (as was originally remarked by Herrick) with the Earth's anthelion, or antisolar point at the time of the appearance. Two notable and well-determined meteor radiant points in April and May, near the ecliptic and to the stars *α*, *ι Virginis*, have been recorded very close to this place, of which the possible accordances with this newly observed, pretty rich, and apparently long enduring meteor shower may either be accidental or will perhaps hereafter receive some more distinct corroborations from further observations. A shower of 60 reddish, moderately bright, slow moving shooting stars, appearing in two and a quarter hours, was seen in America on the night of April 18, 1841, by Professor Forshey, who first noticed their frequency at about $8^h\ 30^m$ P.M., and who determined the exact place of their radiant point, not quite halfway from *Spica* towards *θ Virginis* at 198−8. The tracks of all but five of these sixty shooting stars diverged with deviations of less than 10° from a common centre at this place, the meteors leaving no streaks, and resembling each other in all respects very closely, although quite different in their general appearance from the swift streak-leaving members of the well-known August meteoric shower.† Another approximate agreement with the direction of the April

* *See* the last Annual Report in these *Notices*, vol. xxxviii., p. 223. Von Niessl's first rough position, near *ε Cassiopeiæ*, is there given as the approximate direction of the calculated paths; but the place at 18+57, found at last, coincided, it now appears, more exactly with the position, as described above, of the star *δ Cassiopeiæ*.

† Briefly extracted from a notice of the shower, with some remarks on its appearance, by E. C. Herrick, in the *American Journal of Science*, vol. xlii., p. 395, April–October, 1842. A radiant point of some bright meteors, on April 10, 1864, was also noticed by Professor Herschel, near *δ Virginis*, confirming Heis, at 192+4; these *Notices*, vol. xxiv., pp. 213–215.

"Virginids" is that of the real course and radiant point of the detonating fireball, described in the foregoing list, which burst over the neighbourhood of Edinburgh on the evening of May 12, 1878. There is reason to suppose that this fireball was aërolitic, from the statement that a sound like a deep peal of thunder was heard at Galashiels at an interval of time after its disappearance there corresponding exactly to the distance of its fiery-looking course and passage over the Pentland Hills, about 30 miles from the observer. Its real course to this point, as traced from some well accordant observations, was directed from a radiant point over York and Hawick, at about the altitude 22°, 35° east from south, only the altitude being uncertain to the extent of five or ten degrees. The concluded place of this large meteor's radiant point, at 214−7, is therefore less certain and exact in declination and latitude than in R.A. and in longitude on the ecliptic. But with the above apparent altitude, which accords best with the several combined descriptions, it yet appears to have been not far (6° or 8° north) from the ecliptic, in a degree of longitude 12° or 15° east from *Spica*, and occupying accordingly, near the above noted star-showers' radiant points, a point nearly midway between the stars *ι*, *κ Virginis*.

Although the true Lyrids were extremely scarce on April 19–20, 1877, Mr. Denning found, from the foreshortened tracks of five or six seen in a watch of about five hours, a very exact radiant point of the shower at 269+35; while, from thirteen tracks recorded in two hours on the same night, Mr. Corder deduced a position at 275+35, agreeing more nearly with the earlier exact determinations of its place at about 277·5+35. The apparent paths of seven Lyrids recorded in about an hour on the morning of April 21, 1869, by the Director of the Urbino Observatory, Professor Serpieri, exhibited a radiant point near the place found by Mr. Denning, at 267+35, as obtained from a projection of their tracks by Schiaparelli, who remarked that this position of the Lyrid centre agrees better than any previous one with the radiant point at 270·4+33·5 of the comet I, 1861.* In April, 1874, Dr. Weiss, of Vienna, began to collect and compare together recorded observations of the April Lyrids, with a view to extracting, if possible, from the projected paths a place of the meteor radiant point agreeing exactly with the corresponding radiant position of the meteor-comet. A cursory inspection of some of the recorded tracks led him to regard a distinct centre of the shower as possibly assignable at 265+35, in approximate agreement with the cometary place. But the lack of observations of this poorly represented special star shower has scarcely yet permitted the attainment of very positive determinations; and the question of good

* *Bullettino Meteorologico di Urbino*, anno 1869, p. 20. The observation, with the remark by Schiaparelli, is also described at p. 295 of the vol. for 1869 of the *British Association Reports*.

agreement with the comet's radiant point, or of possible oscillations from it at different times, which the radiant point of the April Lyrids may present still eludes satisfactory solution and establishment by such inquiries, from the actual scarcity of observations of its meteors which the absence of strong intensities of its displays since its last maximum appearances in the years 1863–64, has for a long time uniformly prevented observers from collecting in nearly all the later recurrences of its traditionally interesting annual returns.* A shower at 265+38 occurs as nearly the richest of each series in the early April and early May periods of Mr. Denning's admirably arranged and wonderfully copious Catalogue of his reductions from the Italian Meteor Association's Observations of the year 1872. This prominent April and May shower near *θ Herculis* apparently coincides with Schiaparelli's radiant point (SZ. 68) of May 18, at 263+38. Later showers in Schiaparelli's list (SZ. 75, May 25, 277+39, and SZ. 79, June 14, 280+35) are noticeable in the same neighbourhood, the latter agreeing with showers of Schmidt, Greg, and Tupman in June, and being identified (at 285+32, on June 15–17)† by one of two positions only which Mr. Denning's list contains, of meteor showers that he observed in June. A shower at 258+37 was also among those which he observed in the year 1877 towards the middle of July.

The commonly supposed adherence of meteors and meteor showers for very great lengths of time to nearly fixed radiant points or average directions of their streams, to whose fancied rule of fixity these meteor showers in April to July, nearly concentric with the April Lyrids, seem to offer no exception, is more abundantly illustrated by many examples occurring in Mr. Denning's extensive Catalogue of his Italian meteor shower reductions (which contains about 180 primary or distinct positions, and about 135 others nearly identical with them in one or more adjacent months) than in any former Catalogue of individual

* *The Reports of the British Association*, vols. for 1863, p. 325, and 1864, p. 98, and for some later years, contain some fragmentary descriptions. But the particulars of the abundant shower of April 21, A.M., 1863, were not dwelt on, from their length, in that year's Report, and it does not now appear probable that any good additional information regarding the appearance of that very notable star shower could be recovered for examination.

† Another example of very close corroboration of one of Schiaparelli's showers (SZ. 123, July 30, 345+40, forming the last of a "Lacertid" group at about 337+41), is the observation by Mr. Hind on August 2, 1875, of a marked shower with a most decided radiant point at *o Andromedæ* (344+41·5). The place of Schiaparelli's shower was by some confusion given wrongly as 335+40 in a notice of this observation at p. 216, vol. for 1875, of the *Reports of the British Association*; and again its No. as 135, and the place of Mr. Hind's shower as 340+42 in Professor Herschel's list of comet and meteor shower accordances, these *Notices*, vol. xxxviii., p. 384. The first of Schiaparelli's four "Lacertid" showers (SZ. 98, July 18, 332+35) was well confirmed last year by a good view obtained on July 25, 26, 1878, by Mr. Denning of a rich meteor stream with a very exact radiant point near *a Lacertæ*, at 332+37.

showers. The well-known meteor origin of the August Perseïds thus also remains in distinct and apparently never entirely suspended activity at a nearly fixed focal point during all the months from July to December. But the orbits both of the Perseïds and of the April Lyrids are well known to be prodigiously long ellipses; and as orbits of that form, of these long enduring concentric meteor showers, are at the beginning and end of the long periods of their durations (and often in a much shorter space of days in many cases) almost the antipodes of each other in their figures and positions, it would at present be taking too confident, although perhaps not an impossible view of their past history and derivation to regard as proceeding by easy variations from a single original source or datum channel, orbits of such vast lengths and periods, the spheres of whose revolutions now lie in tracts of space apparently quite incongruous, and so singularly remote from each other in their distances and directions. Determinations of the dates of maximum, and of more precise durations and centres of radiation of nearly coincident meteor showers, so as, if possible, to separate from each other overlapping meteor systems, appear accordingly in the recent great advances of our knowledge of the numbers and diversities of ordinary meteor streams, to be the best and most certainly effective means of arriving, by the help of continued observations, at a true solution of this interesting and by no means simple and very readily comprehended question.

The later showers of the year observed in 1877, and described by Mr. Denning in his list, include a large number of well determined radiant-point positions, often well marked on special nights, forming, together with the earlier observations of the year, a large and most invaluable collection. Only a few of its latest and more conspicuous determinations have already been noticed (in the last of these Reports); while, from the numerous exact positions now clearly set forth, and individually described, a much larger selection of such important points for future verification might very easily be extracted; but their minute details, and the somewhat excessive length to which this review has already extended, will not permit their recapitulation here, to invite observers more expressly in the course of future years to devote to the many well-marked showers and conspicuous observations which the list contains the amount of active attention and vigilance which they will require to reaffirm them, and corroborate them, and if possible to extend their indications.

One of the results obtained by Mr. Denning's observations in 1877, which may perhaps assist to explain the long observed duration of the August Perseïds, was the detection in July of two radiant points near the stars θ, and α, κ Persei distinct from each other and from the true radiant point of the Perseïds of August 10. The shower near θ (D. 1877, 64) Mr. Denning found to be confirmed by his Italian reductions; and a very remarkable

proof of its separate existence, with a precise determination of its date and radiant point, was obtained last year by Mr. Denning's observation on the night of July 31, 1878, and on a few immediately adjacent nights, of an abundant shower of streak-leaving shooting-stars resembling the true Perseïds in all respects excepting in the shortness of their courses, with a radiant point about 3° south of the cluster χ *Persei*, and scarcely six or seven degrees distant from the focus of the August Perseïds, at $33+52$. Forty-four meteors proceeding from this point (or Perseïds II., as they are now denoted) were recorded on the nights of July 30–August 1, with a strong maximum of their numbers (21 meteors) on the night of July 31. Only five or six true Perseïds (or Perseïds I.) were at the same time visible on those nights; while on August 7 and 8, when the sky was again clear enough for observations, the shower of Perseïds II. had ceased entirely, and the true Perseïds with their usual radiant point were only just beginning to be visible in some abundance. The new shower was not distinguishable before July 21, although fifty-nine of its meteors were afterwards recorded; and it was thus of very brief, although of remarkable, activity during the short period of its soon following maximum display. It coincides closely in its radiant place with that of a shower at $31+55$, noted as "exact" by Schmidt for a period of a little later date, between August 3 and 12.

A not less well-defined and conspicuous star shower was, at about the same time, observed by Mr. Denning, on the nights of July 26–30, 1878, producing on those nights fifty fine train-less slow moving meteors, with long courses from a very exact radiant point near δ *Aquarii*, at $341-13$; eight of these meteors in three quarters of an hour before midnight on July 30 being seen diverging from the radiant point which was then hardly risen, or but just rising, near the east horizon; and of the rest, which were visible on that and the earlier nights, twenty-two were recorded on July 27.* On the night of July 31, however, among nearly one hundred meteor tracks recorded, only two or three belonged to this fine and active shower, which therefore appears to have reached a maximum of its bright, shortlived display in the interval between the dates of July 27 and 30. An almost identically similar observation of this shower was made on July 27–31, 1870, by Captain Tupman, and its appearance about the end of July and the beginning of August has been noted independently by Heis, Neumayer, Schmidt, and Weiss, at points coinciding evidently among several known contemporaneous ones in *Aquarius* with this one of greatest note and prominency in that constellation. A bright and conspicuous star-shower occurring three months earlier, near α *Aquarii*, in this region, was observed by Captain Tupman on April 29–May 2, 1869–70, and to this important star shower

* *Nature*, vol. xviii., p. 356.

and to its new and accurately defined successor in *Aquarius*, both of them very distinctly described by Captain Tupman, the distinguishing titles of "May 1 Aquariads" and "July 30 Aquariads" may now very appropriately be assigned. As a shower of special date, and of frequently observed recurrence, future watches for the July 30 Aquariads, as well as for the new minor Perseïd system just described, will hereafter be as desirable and as needful to trace the degree of annual regularity or the intermittences of their returns as the watches for the Lyrids, Geminids, Orionids, and Taurids, which have been kept continuously with pretty successful vigilance for this purpose during recent years.

Three long-pathed meteors of the May 1 Aquariad shower were mapped at Writtle on May 4, 1878, by Mr. Corder, giving a position of the radiant point eight or ten degrees of right ascension in advance of the exact place found by Captain Tupman, at 334−1. Although this place and the date are both in better agreement than those of the main shower with the theoretical radiant point at 337, 0, of a meteor shower from Halley's comet at the point of its closest approach, about May 4, rather near to the Earth's orbit, yet its late hour of rising and the quickly approaching dawn, coupled with obstinately cloudy skies, have for so many years prevented a good view of this shower from being seen, and good positions of its radiant point from being obtained, that nothing confirmatory of a possible cometary origin of this meteor shower has yet been ascertained by observations. Mr. Corder also noted eleven Lyrids on April 20, 1878, with a radiant point at the same place, 275+35, as that which he observed in 1877.* Mr. Denning's observations at Bristol included thirteen Lyrids on April 20–22, the radiant of the shower being well defined at 272+32, and the appearance of a few of its meteors on April 22 being unusually late indications of its continuation on a date generally conspicuous hitherto for the total termination and expiration of the Lyrid meteor stream.†

Of the other major star showers of the past year, a generally good view was obtained of the Perseïds I. on the night of August 10, 1878, although in the strong moonlight, which lasted until nearly daybreak, its smallest meteors were invisible, and the sky was everywhere overcast on the nights of August 9 and 11. The horary number seen at Bristol and at Writtle was, at its maximum between 14^h and 15^h, about 55 conformable and 15 unconformable meteors, a number slightly less than that observed by Mr. Denning at the corresponding time, and in an almost equally favourable state of the sky, on August 10, 1877. The intensity of the shower was therefore not more considerable than it had remained previously for the last few years, and only

* The *Observatory*, vol. ii., p. 103.

† *Ibid*, p. 71; and the above quoted paper by Mr. Denning, in these *Notices*, "On the April Lyrids &c."

one Perseïd of great brightness was seen by Mr. Corder at 14^h 28^m on August 10, which illuminated surrounding objects with a flash of light. Mr. Corder noted two special radiant points, besides the usual general centre of the shower at $43+56$, at $45+57$, and $47+58$; the latter of a perfectly stationary meteor, and the former one of several foreshortened tracks all seen at about 13^h.*

Mr. Denning and Captain Tupman (the latter observing at St. Moritz, in Switzerland) were led independently by carefully mapped, and in general foreshortened meteor paths near the radiant point, to regard this point as double, with the positions,

Denning, at $44+59$; and $42{\cdot}5+54$;
Tupman, at $46+57{\cdot}6$; and $38+56$.

The two pairs of centres thus independently obtained, although not absolutely coincident, are yet seen to corroborate each other very strikingly, and the first of the two points (in larger right ascension and declination) is well confirmed by Mr. Corder's two special positions, each of which may be regarded as very well determined. Its average place from all the four data is at $45{\cdot}5+57{\cdot}9$, while that of the other point is, by two positions, at $40{\cdot}2+55{\cdot}0$.

In the pages of the *Observatory*, from which these particulars of Mr. Corder's and Mr. Denning's observations are extracted, and in a contemporary communication by Mr. Backhouse, in the *Astronomical Register*,† as well as in the part of the past year's Report of the Luminous Meteor Committee to the British Association, which describes Captain Tupman's and the other observations, here noticed, of the August Perseïds in 1878, an apparently complete explanation of the above, and of some other recent observations of the August meteor shower, was presented, which, however fit and satisfactory it appeared to be at its first proposition, must now be retracted as inadmissible, as it has been since discovered, on submitting the newly discerned agreement to a critical examination, to be founded on an erroneous supposition. The theoretical radiant point of the comet 1870 I. is not, as it was represented in the present writer's lists, at $43{\cdot}5+55$, but at $25{\cdot}5+45$;‡ and it follows from this that neither the latter of the two above found radiant foci of the Perseïds in

* The *Observatory*, vol. ii., p. 160.

† *Ibid.*, p. 164; *Astronomical Register*, vol. xv., p. 280, November 1878; *British Association Reports*, vol. for 1878, Appendix on Meteor Showers.

‡ A few errors of the list (as published originally in the volume for 1875 of the *Reports of the British Association*) have from time to time been detected, and were lately rectified in the volume of the same Reports (and for the most part also in the list of "Accordances &c." contained in that of these *Notices*) for the past year. Should other errors of the list make necessary any very important corrections of its indications, like the present one, such future emendations, if they should arise, will be made a further subject, whenever the occasion may permit, of communication to the Society.

1878, nor the exceptionally bright display of the Perseïd shower on August 9–12, 1871, can have, as was surmised, any real import assigned to them of possible connection with the passage near the Earth's orbit, at a descending node on August 12, of the telescopic comet 1870 I. The elements of this comet's orbit are, in fact, widely different from those of the true meteor comet, 1862 III., which agrees exactly in the date and position of its radiant point with the annual 10th of August meteor shower of "Perseïds I." While the meteor swarm of this comet's track accordingly agrees well with the first of the above two radiant centres, and with that (at 44+56) generally accepted of the ordinary Perseïd stream, it is now, on the other hand, clearly manifest that a similar meteor train following the track of the comet 1870 I. cannot possibly be assumed either to have produced the second of the two separately active radiant centres recorded in last year's display, or to have furnished (as was most aptly and independently inferred by Mr. Denning and Mr. Backhouse) the extraordinary abundance of shooting stars which rendered the return of the Perseïds in the year 1871 an exceptionally rich and brilliant exhibition of the August meteor shower.

Cloudy conditions of the sky and bright moonlight were unfavourable for observations, after August last, of the principal star showers of the past year, and only occasional and scanty notes of their appearances were in consequence obtained. A pretty abundant shower of the Orionids was observed by Mr. Corder on October 22, 1878; thirty-five out of ninety-nine meteors seen in four or five hours' watch belonging to the shower, or to one of three centres which their tracks presented at *ν Orionis*, and near *η* and *ν Geminorum*. The shower was also seen by Mr. Denning, at Bristol, on the same night; eleven Orionids, among thirty-four meteors seen in two hours and a half, being counted. But no other views of the shower, from the prevalence of clouds, could be obtained on its principal maximum dates of October 18–21. Watches for the Leonids were also unavailing at the usual time of their annual return, from clouds, and no views of any meteors of this stream, or of the Taurids, were obtained. In spite of the cloudy and unsettled weather, attentive watches were everywhere maintained for an expected reappearance of the Biela star shower on the 24th and 27th, or on other nights of the last days of November 1878, but without success, a complete dearth of these meteors having been recorded by the few observers who obtained clear views of the sky at intervals during the assigned period of the expected shower. This was Mr. Denning's experience at Bristol on the 26th, and also the writer's, at Newcastle-on-Tyne on the 23rd and 28th. The sky in Berwickshire was quite clear throughout the night of the 27th, and an observer there who saw the Biela shower in 1872, and who was informed of the expected date of its return last year, looked out repeatedly until daybreak for symptoms of its recurrence, without, however,

observing the appearance of a single meteor. Mr. E. F. Sawyer relates, at Boston, that he descried one Andromede in three hours' watch on the 23rd, and two Andromedes in four hours on the 26th, but none in about ten hours' watch on November 24, 29, and 30, the other November nights of the shower being overcast.* So far as can be ascertained, the cluster of these meteors appears not to have been encountered by the Earth during its passage across their path in November 1878; but it should be borne in mind that a favourable time for its appearance, and for a reobservation of the meteor shower, may be pretty certainly expected to occur again between the 23rd and the 30th of November in the present year.

Scarcely any Geminids were seen in December, full moonlight and the heavy storm of frost and snow which prevailed on the principal nights of their annual return having entirely prevented observations. The shower of the Quadrantids of January 1–2 was seen in clear sky at Newcastle-on-Tyne, by the writer of this notice, on the evening of January 1 and morning of January 2, and again with almost equal brightness on the evening of January 2, 1878, producing eight or ten fine shooting stars per hour, in each watch, of which the apparent paths were not, however, mapped or noted. At Bristol Mr. Denning traced the tracks of fourteen Quadrantids; and of no other shooting stars seen in a sky about one-third part clear between $6^h\ 15^m$ and $6^h\ 35^m$ A.M. on the latter morning, with a radiant point of the shower at $230+51$, clearly showing a great activity of the shower, and a brightness of its display perhaps not much inferior to that of its appearance in January 1878.

* The *Observatory*, vol. ii., p. 339.

Papers read before the Society from February 1878 *to February* 1879.

1878.

Mar. 8. On a new Variable Star in the constellation *Ara*. J. Tebbutt.

On certain groups of Stars with common proper motions. Prof. T. H. Safford.

On the solution by trial of Lambert's theorem in Olbers's method for the computation of parabolic orbits. R. H. M. Bosanquet.

Observations of Occultations of Stars by the Moon, and of phenomena of *Jupiter's* Satellites made at the Royal Observatory, Greenwich, in the year 1877. The Astronomer Royal.

On the Telescopic Observations of the Transit of *Venus*, 1874, made in the expedition of the British Government, and on the conclusion to be deduced from those observations. E. J. Stone.

Radiant Points of Shooting Stars from the Italian observations in 1872. W. F. Denning.

Observations of Shooting Stars in 1877. W. F. Denning.

On the proper motion in Right Ascension of 92 *Draconis*. A. W. Downing.

On the supposed influence of a mass of brickwork upon the errors of a Transit Instrument in its neighbourhood. J. T. Plummer.

Galileo's Trial before the Inquisition in the light of recent researches. Sedley Taylor.

List of known accordances between Cometary and observed Meteor Showers. Prof. A. S. Herschel.

Ephemeris for physical observations of *Jupiter*, 1878. A. Marth.

On Hansen's terms of long period in the Lunar Theory. E. Neison.

On Mr. Stone's note in the January number of the *Monthly Notices*. R. A. Proctor.

On the determination of the axial position of *Mars* with respect to the Earth at any epoch. R. A. Proctor.

Ephemeris of *Mars* for the Opposition of 1877. D. Gill.

April 12. On the duration of Meteor Showers. R. P. Greg.

The luminous spot on *Mercury* in Transit. B. G. Jenkins.

A Comparison of the observations of contact of *Venus* with the Sun's limb in the Transit of 1874, December 8, made at the Royal Observatory, Cape of Good Hope, with the corresponding observations made at the stations in the Parliamentary Report, and a discussion of the results. E. J. Stone.

Photography at the least refrangible end of the Solar Spectrum. Captain Abney.

Observations of the companion of α *Canis Majoris* with the Transit Circle of the U. S. Naval Observatory. J. R. Eastman.

Early Transits of *Mercury*. Rev. S. J. Johnson.

Observations of polar and equatoreal diameters of *Mars* near Opposition, 1877. R. L. J. Ellery.

Note on the table, page 70, vol. ii., of *Dun Echt Observatory Publications*. Lord Lindsay.

May 10. β Leonis and B.A.C. 3992. S. W. Burnham.

The Transit of *Mercury*, May 6, 1878. G. F. Chambers.

The Transit of *Mercury*, May 6, 1878. C. L. Prince.

Observations of the Transit of *Mercury*, 1878, May 6, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The April Lyrids and contemporary Meteor showers. W. F. Denning.

The Transit of *Mercury*, 1878, May 6. Prof. C. Pritchard.

Observations of the Transit of *Mercury* 1878, May 6, made at Antwerp. Baron von Ertbon and MM. de Boë and Schleusner.

Observations of Ingress during the Transit of *Mercury*, May 6, 1878. F. C. Penrose.

The Transit of *Mercury*, 1878. J. Brett.

Observations of the Transit of *Mercury* of 1878, May 6. A. C. Ranyard.

Note on the comparative brightness of the different parts of the disk of *Venus*. A. C. Ranyard.

The Transit of *Mercury*, May 6, 1878. R. A. Proctor.

Note on the duplicity of the companion to *Rigel*. S. W. Burnham.

Observations of the Transit of *Mercury*, May 6, 1878. J. J. Cole.

On the heat of the Stars. J. J. Waterston.

June 14. On the position of λ *Ursæ Minoris*. Prof. T. H. Safford.

Observations of the Transit of *Mercury*, May 6, 1878, at Princeton, New Jersey. Prof. C. A. Young.

On the late Opposition of *Mars* (extract from a letter to the Astronomer Royal). Maxwell Hall.

Observations of the Transit of *Mercury*, 1878, May 6 (extract from a letter to the Astronomer Royal). Maxwell Hall.

On the spectrum of the New Star in *Cygnus*. T. W. Backhouse.

On the measurement of the inequality of the pivots of Transit Instruments by means of the Spherometer-Caliper. Prof. W. Harkness.

A reply to Mr. Proctor's note in the March number of the *Monthly Notices*. E. J. Stone.

Observations of the Transit of *Mercury* made at the Allegheny Observatory. S. P. Langley.
New Double Stars. S. W. Burnham.
Note on the great Comet of 1861. J. Tebbutt.
On the Atmosphere of *Mars*. R. S. Newall.
On a Solar Thermometer Couple to measure the radiant force of daylight. J. J. Waterston.
Transit of *Mercury*, May 6, 1878. J. I. Plummer.
Note on the Belgian observations of the Transit of *Mercury*. Capt. W. Noble.
On the mean Solar Parallax as derived from the observations of the Transit of *Venus*, 1874 (communicated by the Astronomer Royal). Capt. G. L. Tupman.
Observations of the Transit of *Mercury*, May 6, 1878, at Dun Echt Observatory. Lord Lindsay and Dr. R. Copeland.
Ephemeris for finding the position of the Satellite of *Neptune*. A. Marth.
The proper motions of certain Stars in the Greenwich Seven Year Catalogue for 1864. A. W. Downing.
Spectroscopic results for the motions of Stars in the line of sight, made at the Royal Observatory, Greenwich. III. Communicated by the Astronomer Royal.
On the existence of bright lines in the Solar Spectrum. W. H. M. Christie.
The Transit of *Mercury*, 1878, May 6. N. de Konkoly.
On some terms of long period in the mean motion of *Mars*. E. Neison.
Note on a remarkable property of the analytical expression for the constant term in the reciprocal of the Moon's radius vector. Prof. J. C. Adams.
On the Photographs of the Transit of *Venus* (communicated by the Astronomer Royal). Capt. G. L. Tupman.

Nov. 8. Note upon the proper motion of 5 *Serpentis*. T. H. Safford.
Transit of *Mercury*, May 6, 1878, observed at Cadiz. A. T. Arcimis.
Discovery of Encke's Comet. J. Tebbutt
Additions to the theory of the Sidereal System. Maxwell Hall.
Measures of the B Line in the spectrum of a high Sun. Prof. C. P. Smyth.
Double Star observations made in 1877–78 at Chicago with the 18½-inch Refractor of the Dearborn Observatory. S. W. Burnham.
Account of additional buildings and proceedings at the Oxford University Observatory. Prof. C. Pritchard.
Observations of the periodic Comet of Tempel, 1878. Prof. C. Pritchard.

On Newcomb's correction to Hansen's value of the secular acceleration. E. Neison.

The total Eclipse of the Sun, July 29, 1878. F. C. Penrose.

Some remarks on the total Solar Eclipse of July 28, 1878. A. Schuster.

On the progress of the reductions in connection with the Ascension Expedition. D. Gill.

The Solar Eclipse of July 29, 1878. Prof. H. Draper.

Note on some remarks by Mr. Maxwell Hall on the Opposition of *Mars*. D. Gill.

Note on the presence of particles of Meteoric iron in the atmosphere. A. C. Ranyard.

On the results of the Meridian observations of the *Mars* comparison stars. D. Gill.

Note upon the star Bradley 2935. Prof. T. H. Safford.

On a portable Star Finder for altitude and azimuth telescopes. E. H. Liveing.

Dec. 13. Note on a Determination of the Mass of *Mars*. The Astronomer Royal.

On a new variable star, *ι Andromedæ*. J. E. Gore.

Total Eclipse of the Sun, July 29, 1878. W. H. Pickering.

Measure of the diameter of *Mercury* made at the Princeton Observatory, May 6, 1878. Prof. C. A. Young.

On the Conjunction of *Mars* and *Saturn*, 1879, June 30. Astronomer Royal.

Note on a phenomenon seen in the occultation of a Star at the Moon's bright limb. W. H. M. Christie.

Phenomena of *Jupiter's* Satellites, 1877–78, observed at the Stonyhurst Observatory. Rev. S. J. Perry.

Addition to the paper on the mass of *Mars*. The Astronomer Royal.

Reduction of the north polar distances of the Cape catalogue for 1860 to Auwers' standard. A. W. Downing.

On a variable Diaphragm for use in solar and sidereal observations. F. W. Levander.

A complete general solution of the problem of disturbed elliptic motion. E. Neison.

Notes on the late Admiral Smyth's "Cycle of Celestial Objects," vol ii., commonly known as the Bedford Catalogue. H. Sadler.

On Observations of *α Centauri* made with the Heliometer at Ascension in 1877. D. Gill.

On the visibility of Stars in the *Pleiades* to the naked eye. Prof. Winnecke.

Note on some hitherto unnoticed features near the lunar crater *Hyginus*. Lord Lindsay and Dr. Copeland.

1879

Jan. 10. Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* Satellites made at the Royal Observatory, Greenwich, in the year 1878. The Astronomer Royal.

On the practical advantages of Hartnup's method of testing Chronometers. A. E. Nevins.

On the observed errors of Bouvard's Tables of *Saturn*. E. Dunkin.

Note on *Hyperion*. Prof. A. Hall.

Observations of the Transit of *Mercury*, May 6, 1878, and of the occultation of *Mars* by the Moon, June 3, 1878, made at the Glasgow Observatory. Prof. R. Grant.

On the reduction of the north polar distances of the first Melbourne general catalogue for 1870 to Auwers' Standard. A. W. Downing.

Ephemeris for determining the positions of the Satelllite of *Uranus*, 1879. A. Marth.

Notes on Meteors observed November 27, 1878. Lord Lindsay and Dr. Copeland.

List of Public Institutions and of Persons who have contributed to Library &c. since the last Anniversary.

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Prof. G. V. Schiaparelli.
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N. G. Wilkins, Esq.
Dr. R. Wolf.
Prof. C. A. Young.

ADDRESS.

Delivered by the President, Lord Lindsay, on Presenting the Gold Medal of the Society to Professor Asaph Hall, U.S. Navy.

Your Council has this year awarded the Gold Medal of the Society to Professor Asaph Hall

For his discovery and observations of the satellites of *Mars*, and his determinations of their orbits.

It has been usual for your President to state the reasons which have influenced the Council in their awards, and to give a brief history of the discovery, or research, which they have held worthy of such high esteem, and, in following the example of my predecessors in office, I would crave your indulgence if I slightly deviate from custom in one particular.

I allude to some of the work of your Medallist which had rendered his name already familiar at the time he announced his great discovery to the world.

An examination of the writings of Professor Hall show that there are but few departments of astronomy to which he has not paid some attention, combining the skill of the observer with the labours of the mathematician.

From 1858 to the present time almost every volume of the *Astronomische Nachrichten* contains notices of his zealous observation of minor planets and comets. Not content with mere observation, he has in many cases given ephemerides, and has calculated elements, among which may be noticed those of (60), (66), (73), (81), (124), all of them refined pieces of work based on normal places, and in some instances taking into account the perturbations due to *Jupiter* and *Saturn*.

The early history of Mr. Hall affords a bright example of what perseverance and determination may effect in overcoming even the most adverse circumstances.

Born at Goshen on October 15, 1829, Mr. Hall received his early education at the hands of his father and at the village school. In 1842 he was left an orphan, and from comparative affluence he was reduced to work for his living. He served for some time as an apprentice to a carpenter, devoting his leisure hours to the study of geometry and algebra.

In 1856 he studied one term under Brünnow at the Michigan University, whence he went to Cambridge, Mass., and entered the Observatory under Professor W. C. Bond. He applied himself with the greatest diligence to all matters connected with the Observa-

tory, as he was determined—to use his own words—to make himself so useful that they would not care to let him go. Strong and in good health, he found time to study, and worked hard on orbits and the theory of perturbations. He remained at Cambridge until August 1862, when he was appointed one of the aids in the Naval Observatory, Washington, and in May the year following he was commissioned Professor of Mathematics.

In 1863 he published a Memoir on the Solar Parallax deduced from observations of *Mars*, with equatoreal instruments, made at Upsala, Santiago, Washington. Combining all the results, he found,

From Upsala and Santiago	$\pi = 8''.859$	$w.$ 43·81
Washington and Santiago	$\pi = 8''.810$	$w.$ 24·60,

with the concluded result of all the observations of *Mars* in 1869,

$$\pi = 8''.8415.$$

This Memoir he supplemented in 1866 by an examination of 1181 observations used for the parallax determination, and showed conclusively that the method of observing the planet on two wires sufficiently wide apart to cut off small segments of the planet's disk is far preferable to the method of tangents.

In a Memoir communicated to the *Astronomische Nachrichten*, No. 71, p. 191, on the "Positions of the Fundamental Stars," he offers some very sound suggestions, considering that these determinations should be made a *special problem*, to which the undivided attention of the observer should be given. He considers that the instrument should not exceed 5 inches aperture, with circles not greater than 30 inches, and that the objectives and oculars should be interchangeable, in order to eliminate as far as possible constant errors and flexure. Each series of observations should be made by a single observer, who should be an experienced astronomer. He goes on to show, if the number of stars were small, limited perhaps to the 47 chief stars of the *Berliner Jahrbuch* with the addition of a few circumpolar stars, that their positions might be advanced to a degree of accuracy almost hopeless under the present methods of observing.

Your Medallist this year (1868) made a remarkable observation of an occultation of *Aldebaran*, the immersion of which was seen at $0^h\ 3^m\ 10^s{\cdot}6$ Washington mean time. The Moon was invisible at the time and the star was only $8°\ 12'$ from the Sun's centre. This occultation, though given in the *Jahrbuch* and in the *Monthly Notices*, was not in either the American or English *Nautical Almanacs*, nor in the *Connaissance des Temps*.

Professor Hall was sent by his Government to observe the solar eclipses of 1869 and 1870, and though his notes on these observations are interesting, I will not dwell upon them, as they will be fully treated in vol. xli. of your *Memoirs*.

In 1870 he sent an interesting paper to *Silliman's Journal* on the secular perturbations of the planets.

Following the steps of Lagrange, he points out, as had been already done by Leverrier, that the final equations from which the secular perturbations are derived rise to the degree denoted by the number of planets considered and in our system will be of the eighth degree. The conditions necessary for the stability of the system are, first, that the eight roots of the equation for "g" (on which depend the excentricity and the longitude of the perihelion) shall be real and unequal, in order that there may be no terms, outside the circular functions, containing the time as a factor or exponent, which therefore would increase indefinitely; and, secondly, it is necessary that the coefficients, determined by the initial values of the excentricity and perihelion, may not be great, in order that the excentricity may not increase so as to render divergent, the series, which have been assumed in the solution to be rapidly convergent.

When it is required to compute for very remote epochs, he shows that the value of the coefficients of "g" which are multiplied by the time must be very carefully considered. These depend on the values of the assumed masses of the planets, and are usually determined by neglecting terms of the third order.

Leverrier shows that the terms of the third order may produce corrections of the values of "g" amounting to three or four-tenths of a second; probable uncertainties in the assumed values of the masses of the planets may give rise to errors of nearly two tenths of a second. Thus it is evident that for remote epochs calculations must be untrustworthy, since when the time is great the errors in the value of "g" may completely change the character of the circular functions.

Professor Hall next points out that, to obtain satisfactory solutions to the problem, our knowledge of the planets' masses must be greatly increased.

Assuming that in time the masses of *Mars* and *Jupiter* will be accurately learnt from the theories of some of the minor planets, he considers that we have to our hand the instrumental means of making accurate determinations of the masses of *Saturn*, *Uranus*, and *Neptune* by a more complete investigation of the theories of their satellites.

Now follows the only passage I have found in which I cannot entirely agree with your Medallist. He says:—"When the novel and entertaining observations with the spectroscope have received their natural abatement, and have been assigned their proper place, it is to be hoped that some of the powerful telescopes recently constructed may be devoted to this class of observation."

The volume of the *Washington Observations* for 1867 contains a valuable catalogue of 151 stars in *Præsepe* whose places Professor Hall determined by comparison with eleven standard stars. The observations were made with the Equatoreal, and

beginning in 1864, were completed in the spring of 1870. In observing, the telescope was clamped in R.A. but free in Decl. The probable errors are $\pm 0^{s}\cdot 043$ and $\pm 0''\cdot 46$. Bright wires and dark field were used throughout, with a power of 132.

In 1871, in *Silliman's Journal*, we have an interesting paper from Professor Hall on the "Astronomical Proof of a Resisting Medium in Space."

Your Medallist shows, from the investigations of Möller and Oppolzer, that the comets of Faye and Winnecke do not by their motions give any indications of the presence of a resisting medium such as Encke assumed to exist.

It is possible that Professor Hall does not dwell sufficiently on the fact that the perihelion distance of Encke's comet is much less than that of either of the others, and that a resisting medium increasing in density in the neighbourhood of the Sun would account for the anomalies in the motion of the comet (Encke's) without affecting Faye's. It would seem, too, that the perturbations of Winnecke's comet have hardly been investigated with all the accuracy required to decide so delicate a question; added to this, the effect of a resisting medium would be much greater on a rapidly moving comet like Encke's. I need hardly say, however, that the whole problem is surrounded with difficulty.

The most interesting paper which Professor Hall has communicated to our Society is to be found in vol. xxxiii. of the *Monthly Notices*; it is on the "Determination of Longitudes by Moon Culminations." He shows here that such determinations are liable to large constant errors. Assuming the telegraphic longitude of San Francisco to be correct (which may safely be done), the determination from 206 Moon culminations was found to be four seconds in error. Treating of the difference of longitude between Washington and Greenwich, he gives the following table:—

Authority.	No. of Culm.	Longitude. h m s	Errors. s
Loomis	150	5 8 9·3	−2·9
Gillis	394	10·0	−2·2
Walker	...	9·6	−2·6
Newcombe	279	11·6	−0·6
Newcombe	163	9·8	−2·4

The conclusions he draws from this investigation are that all determinations derived from Moon culminations, occultations, and solar eclipses give the difference of longitude smaller than the telegraphic value, $5^{h}\ 8^{m}\ 12^{s}\cdot 2$, which he assumes to be the correct value.

The *Astronomische Nachrichten* for 1875, vol. 86, contains several papers by your Medallist. He proposes to utilise the observations of the minor planets to determine the mass of

Mars. Starting from certain formulæ in the *Mécanique Céleste*, he shows which planets would give the best results. It seems probable that the method has lost little or none of its value by the discovery of the satellites, as it seems to be one of the best for giving an independent value.

In treating the Washington observations of *Flora* (8) in 1873, he refers to the determination of the solar parallax according to the method proposed by Professor Galle, demonstrating that an uncertainty of measurement at either of the stations would vitiate the whole angle. He points out, without attempting to explain, the discrepancies which are found to exist between the Observatories of Lund and Dublin in the *Flora* observations of 1873, which are $-0''{\cdot}055$; $+0''{\cdot}080$; $+0''{\cdot}330$; $-0''{\cdot}816$; and $+0''{\cdot}965$. "Whatever may be the cause of these differences between skilled observers, they tend to cast a doubt on the reality of the small quantities which are found in the investigation of stellar parallax."

On December 7, 1876, your Medallist noticed a bright spot on the ball of *Saturn*; on the next day letters were sent to astronomers in different parts of the country, asking them to assist in observing it. It was last seen on January 2, 1877. He combined eighteen observations thus obtained into nine, from which he found the time of rotation of *Saturn* to be

h	m	s	s	
10	14	$23{\cdot}8 \pm 2{\cdot}30$		Mean time.

Sir William Herschel had found $10^h\ 16^m\ 0^s{\cdot}4$, and concluded that this time cannot be in error so much as two minutes. The greater number of the textbooks had $10^h\ 29^m\ 16^s{\cdot}8$, and, by a strange error, Sir J. Herschel, in his *Outlines*, gives $9^h\ 57^m\ 1^s{\cdot}91$, which is the sidereal time of the rotation of *Jupiter*.

In a general investigation of the problem of the shadow of a planet, originating in a wish to determine the form of the shadow of the ball of *Saturn* on the ring, he points out that in a special case the shadow may be sensibly a straight line.

I have thus very briefly brought before you the labours of Professor Hall up to the time of the important discovery for which your Council has awarded him the Medal, and I will now in a few words refer to the unsuccessful searches for satellites of *Mars* which had been made previously to the opposition of 1877.

In 1830 Mädler searched in vain for a satellite of *Mars* during the favourable opposition of that year, and came to the conclusion that if such a satellite existed, and if it possessed the same reflecting power as its primary, it could not exceed the diameter of some 20 miles, since a larger one could not escape discovery under favourable circumstances.

The instrument employed in this search was of $3\frac{3}{4}$ inches aperture, and was the same he afterwards employed in his lunar work; and though at the time the conclusions thus drawn were considered hardly justifiable still, as time wore on and larger

instruments were employed, Mädler's estimate obtained better consideration.

Professor D'Arrest made a search for a satellite in the year 1864. This was again unsuccessful. In a paper in the *Astronomische Nachrichten*, vol. lxiv., p. 74, D'Arrest, assuming the distance of *Mars* from the Earth to be 0·52 and with an assumed mass for the planet, computed the apparent elongation of a satellite which would revolve around the planet in a given time. Thus he showed that an elongation of 70′ would give the satellite a period greater than the period of *Mars* round the Sun, or in other words, greater than 687 days. From this the inference was drawn that it is useless to search for a satellite at a greater distance than 70′.

There is also another note on this subject which seems to have escaped the researches of your Medallist. It occurs in *Stjernehimlen*, by F. Kaiser, translated from the third Dutch edition into Danish by Mathilde Oersted, with a preface by D'Arrest. *Copenhagen*, 1867.

On page 423, note 7, there is the following remarkable passage, which, though nominally by the translator, was probably inspired by Professor D'Arrest:—

"That up to the present time no satellite of *Mars* has been found may possibly be owing to the fact that such a satellite, from the nature of the case, must be very near to its primary, and that any faint star becomes totally extinguished and rendered invisible in the immediate neighbourhood of the brilliant planet.

"Formerly it was the custom to explain the same fact by the contrary reason, viz. by pointing out how difficult it must be to find a satellite of *Mars* at a possibly great distance from the planet. However, by reason of the planet's small mass, this can by no means be the case."

The failures of distinguished observers almost discouraged your Medallist from instituting a fresh search, and the low declination of the planet gave promise of better results for Observatories in the southern hemisphere. However, calling to mind the great optical power and excellence of the Clark Refractor, and encouraged by his wife, Professor Hall thought that there might be a slight hope remaining for ultimate success.

Early in August the geocentric motion of *Mars* being such as to render the detection of a satellite comparatively easy, the search was commenced in earnest. Commencing with faint objects at a considerable distance from the planet, it was soon found that they were nothing but fixed stars, and on August 10 Professor Hall began to "examine the region close to the planet and within the glare of light which surrounded it." Keeping the disk of *Mars* just outside the field of view, sweeps were made all round the planet; but as the definition was very bad, and (as was afterwards learned) the satellites being very near at the time, nothing was found.

The next night, August 11, the observations were resumed, the same method of sweeping being adopted. At $14^h\ 30^m$ your Medallist made the discovery of the outer satellite, a faint object N.F. He had hardly time to complete the observation of position when fog rising from the Potomac river stopped his work. Until the 15th bad weather hindered further observation, and though search was made at 11^h, it was unavailing, the proximity of the satellite to *Mars* rendering it invisible.

On August 16 the satellite was again found on the north following side of the planet, and the observations of this night demonstrated clearly that it was moving with *Mars*, and that, if a satellite, that it was near one of its elongations. It was on the night following, August 17, that, while waiting for and watching the outer satellite, Professor Hall discovered the inner one, and obtained measures of it when at a distance of about 31″ from the centre of the planet.

The last doubts as to the character of the faint objects thus found having been dispelled by the observations of August 17 and 18, the discovery was officially announced by Admiral Rodgers. The appearances of the minor satellite were most perplexing, and I cannot do better than quote the words of Professor Hall. He says: "Still for several days the inner moon was a puzzle. It would appear on different sides of the planet on the same night, and at first I thought that there were two or three inner moons, since it seemed to me at that time very improbable that a satellite should revolve round its primary in less time than that in which the primary rotates."

To set this point at rest Professor Hall watched the satellite throughout the nights of August 20 and 21, and was satisfied that there was but one inner moon, which performed its revolution in less than one-third of the time of the rotation of *Mars*, a case, as he observes, unique in our solar system.

Such, in a few words, is the history of a great astronomical discovery; and it is satisfactory to think that the United States Government has received a reward already for the enlightened munificence displayed in placing so magnificent an instrument in the hands of one so capable of using it.

Of the many names suggested for these moons, your Medallist selected those proposed by Mr. Madan, of Eton—*Deimos* for the outer, *Phobos* for the inner satellite.

The labours attending this search by no means ceased with the attainment of the object in view. For your Medallist, not merely content to publish his crude observations, has reduced them, and from the results has given the elements of the orbits of the satellites.

It would, perhaps, be well to describe the method of observation at this point. Professor Hall commences by saying that, as the satellites were faint objects and were always immersed in the glare of light surrounding the planet, the observations were made with difficulty.

The *modus operandi* was as follows :—The disk of the planet was bisected by one wire of the micrometer as nearly as the eye could judge, while the other was laid on the satellite. As it rarely occurred that both planet and satellite could be seen in the field of view together, it was usually necessary to use the slipping piece of the micrometer, the eye-piece being moved to and fro until the two bisections appeared to be satisfactory. Though at first Professor Hall would have preferred to have had a pair of wires inserted, by which small equal segments of *Mars* could have been cut off, in the manner described in his paper to the *Astronomische Nachrichten*, vol. lxviii., p. 235, he was not willing to break in on his work, and he states that experience has given him confidence in the method he adopted.

The observations thus obtained give polar coordinates or the angle of position and distance referred to the centre of gravity of the apparent disk of the planet, involving corrections for differential refraction and for the figure of the true disk.

For the refraction correction the formulæ, given by Bessel in the *Astronomische Untersuchungen*, vol. i., p. 165, have been used; and the formula,

$$m = \frac{8a}{3\pi} \sin \frac{1}{2} \phi^2,*$$

gives the reduction from the centre of gravity of the illuminated disk to the centre of the true disk.

It will be noticed here that no allowance is made for the varying intensity of illumination of different parts of the disk;

* Where m denotes the distance of the centre of gravity from the centre of the line of cusps,

and ϕ = the angle at the planet;

a = radius of the semicircular part of the disk,

and π = the number 3·14159.

"p" and "s," as usual, denoting the observed angles of position and the distance of the satellite, and "θ" the angle of position of the line of cusps, the errors of p and s arising from the figure of the disk are found by the formulæ—

$$\Delta p = \frac{m}{s} \cos (p - \theta),$$

$$\Delta s = m \sin (p - \theta).$$

A note on this formula was communicated to the Society by Professor Hall and will be found in vol. xxxviii., p. 122, of the *Monthly Notices*. I see that the formula has been there printed

$$m = \frac{8a}{3\pi} \sin^2 \frac{1}{2} \phi$$

for $$m = \frac{8a}{3\pi} \sin \frac{1}{2} \phi^2.$$

any error, however, due to this cause would have contrary effects before and after opposition.

The observations and the corrections thus found, $\Delta\rho$, Δp, $\Delta\rho$, and Δs, are given, and are found to consist of—

For *Deimos*,

52 observations, made on 31 nights, involving 185 comparisons, in position;
50 „ „ 31 „ „ 137 „ in distance.

While for *Phobos* we have

36 „ „ 25 „ „ 123 „ in position;
43 „ „ 25 „ „ 97 „ in distance.

With the exception of three observations of *Deimos*, made by Professors Newcomb, Harkness, and Holden, the whole series were taken by your Medallist.

For convenience in reduction, the times of the observations were then transferred to the meridian of Greenwich, corrected for aberration, and reduced to decimals of a day.

Although many other observations at different Observatories have been made, no series was so complete as that made at the Naval Observatory, Washington; and your Medallist, considering the difficulty of the observations and the probability of each observer having a constant personal error, decided that it would be unwise to throw all the observations at his disposal into one mass; therefore the elements of the satellites are based upon his own observations alone.

The method of computation is as follows:—Taking the observations near opposition and carefully projecting them, he determined the form of the orbits (which were assumed to be circular). The ratio between the axes of the apparent ellipse gives the angle between the line of sight and the plane of the orbit. This, combined with the position angle of the major axis and the place of the planet, gives the inclination of the orbit to the Equator, and also the ascending node on the Equator.

There seems to be an error in the definition of θ at the top of p. 16 of his paper, "Observations and Orbits of the Satellites of Mars &c." Instead of "angle between the orbit plane and the plane perpendicular to the line of sight," we should read "angle between the orbit plane and the line of sight." If this were not so, the formula would run $\cos\theta = \frac{b}{a}$. It will also be perceived that Professor Hall says nothing as to how the approximate period was found. This, however, was probably obtained by combining extreme observations.

From these data he obtained the approximate circular elements, in which

μ is the number of degrees of angular motion in one day.

a the apparent major axis of the orbit seen from a distance unity;

I inclination of the orbits to the Earth's equator
N the longitudes of the ascending nodes } same for both satellites

u the angular distance of the satellite from the node at the epoch.

He then compared the observations with these elements, using Bessel's methods for facilitating the calculation of the positions of the satellites.

He next formed differential equations—98 in the case of *Deimos* and 79 in the case of *Phobos*—for the correction of the following elements:—

The longitude of the node;
The inclination of orbit to Earth's equator;
Longitude at epoch;
Mean angular motion;
Two terms dependent on the excentricity and the line of apsides; and finally, in the case of the distances,
A term dependent on the major axis.

Had this part of the work been carried out in polar coordinates as it was commenced, it would have been perhaps preferable as the more elegant, though in passing to rectilinear your Medallist has followed in the steps of good men, such as Newcomb, von Asten, and Bessel himself.

The coefficients of the equations of condition were computed by Dr. C. Powalky, and were checked by Professor Hall. It will be seen that the normal equations are not given.

The resulting corrections are in general small, the sums of the squares of the residuals being, in the case of *Deimos* 29·07, and for *Phobos* 23·09; whence the probable error of a single observation is found to be, for *Deimos* 0″·391, and for *Phobos* 0″·412.

The excentricity of the orbit of *Phobos* is about $\frac{1}{30}$th, with a probable error of about $\frac{1}{600}$th, and your Medallist most justly concludes that it must be real.

The excentricity of the orbit of *Deimos* is so small that we may consider the circular element of this satellite as practically sufficient for the observations.

An examination of the equations for *Deimos* shows the largest outstanding residuals on August 17. The comparisons and reductions for this date were examined, but no error was found, and your Medallist preferred to let them stand with this remark:—

"The method of rejecting observations after the comparison by means of criterions which are based on the residuals and the probable errors seems to me to rest on a false logic and to lead to the dangerous practice of trimming observations for the purpose

of procuring an apparently accurate result, which, in fact, may be wide of the truth."

The smallness of the probable error of a single observation is the best proof we can have, showing a high degree of accuracy, considering how faint the objects are and under what difficulties the observations were made.

We now come to what may be considered the most important outcome of your Medallist's brilliant discovery, viz. the determination of the mass of *Mars*.

The result he obtains from *Deimos* gives

$$M = \frac{1}{3095313 \mp 3485},$$

and from *Phobos*

$$M = \frac{1}{3078456 \mp 10104};$$

and seeing that these two determinations fall so nearly within the limits of their respective probable errors, Professor Hall has taken the mean by weight as the final result for his observation, thus giving

$$M = \frac{1}{3093500 \mp 3295}.$$

We may assume this determination to be the best in existence, and it may be a matter of interest here to look at the different values which have been from time to time assigned to the mass of *Mars*.

Authority.	$\frac{1}{m}$
Laplace	1846082
Delambre	2546220
Burckhardt	2680337
Airy, 1828	3734602
Hansen, Olufsen	3200900
Leverrier, I	2994790
„ II	2812526
„ III	2948110

Since discovery of Satellites.

Place.	*Deimos* $\frac{1}{m}$	*Phobos* $\frac{1}{m}$
	3054000	
Washington	3095313	3078456
Cambridge, U.S.	3023319	3039643
Glasgow, U.S.	3024348	3400630
Pulkowa	3146996	.....

Laplace, in the *Mécanique Céleste*, gives a value based on the assumption that the mass of the planets varies inversely as their

distances from the Sun. This was afterwards reduced by Delambre. Burckhardt slightly increased the value, which Hansen and Olufsen very greatly decreased in their Tables of the Sun. Le Verrier at different times has used various values for *m*. Commencing with the value given by Burckhardt, he found that it had to be multiplied by the factor 0·895. In vol. iv. of the *Annales de l'Observatoire* he gives a most probable value, and this was again changed in vol. xi. of the same publication.

The determination of this important factor would be materially improved by observations we may hope to make this year, by which a better knowledge of the periodic times of the satellites will be obtained.

Various estimations of the brightness of the satellites have been made, ranging from the 11th to the 15th magnitude in the case of *Deimos*. With respect to *Phobos* much uncertainty has been expressed, but at the same time the opinion seems to be that it is rather brighter than the outer satellite.

Your Medallist mentions having, on August 17, 1877, observed a fixed star which was mistaken for *Deimos*, and thinking that a determination of its magnitude might be of interest to the Society, I requested Dr. Copeland, if possible, to observe it, and I have received the following report:—

January 16, 1879. Altitude of star, 13°±. I noted "Hall's star is about 11½ magnitude, not seen in finders." Stars about 1 m. brighter I could see well in the finder. In the 15¼-inch the star bore illumination of wires well, the place was roughly determined, and agrees with Professor Hall's place within $1^s\cdot5$ and $1''\cdot1$. An accurate reduction will probably reduce this discordance; the more so as the comparison involves a reduction to 1800, in order to use the Berlin Star Map.*

Your Medallist states that this star was a little brighter than *Deimos* at the time he observed it. The above observation is therefore confirmatory of his estimation.

Professor Hall closes his report by giving data for the computation of Ephemerides of the satellites for the present year, when Mars will have a comparatively favourable declination, 18° north. The estimated brightness on October 10 will be 0·63, and on November 4, 0·73, the unit being the brightness on October 1, 1877.

And your Medallist concludes by giving examples of the computation, using the Table prepared for this purpose.

And now, Mr. Hind, may I request you, as the Foreign

* Since writing this I have received another observation of the star, in which the observation note runs thus: "Hall's star is quite 11th mag.; could be well seen when running along the bright wire [of micrometer], which was very well illuminated with the maximum brightness."—R. C., Jan. 27, 1879.

Nothing can be made of the other star this season, as it is hopelessly lost in the twilight. It will be an admirable popular object, as it is only about 7′ or 8′ from a 6-mag. star, and therefore can be readily found with small instruments.

Secretary of the Society, to place this medal in the hands of the Minister of the United States, to be transmitted to Professor Asaph Hall, as the highest mark of esteem in the gift of the Royal Astronomical Society.

Assure him at the same time of the deep interest that we in England have ever felt in watching the progress of our beloved science in the hands of our cousins in the Far West.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

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Lord Lindsay, M.P., F.R.S.

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Sir G. B. Airy, K.C.B., M.A., LL.D., D.C.L., F.R.S., Astronomer Royal.
William Huggins, Esq., LL.D., D.C.L., F.R.S.
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Foreign Secretary.

J. R. Hind, Esq., F.R.S., Superintendent of the *Nautical Almanac.*

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